Research Note 85-28

AD-A163 062

ARI V(INT)^2 SOLDIER/MACHINE INTERFACE DEMONSTRATOR: PHASE I MID-YEAR REVIEW

Azad M. Madni

PERCEPTRONICS, INC.

Raymond C. Sidorsky

ARMY RESEARCH INSTITUTE

for

Battlefield Information Systems Technical Area

SYSTEMS RESEARCH LABORATORY

Franklin L. Moses, Acting Director

DTIC ELECTE DEC 2 7 1985 D E

U. S. Army

Research Institute for the Behavioral and Social Sciences

October 1985

Approved for public release; distribution unlimited.

85 12 26

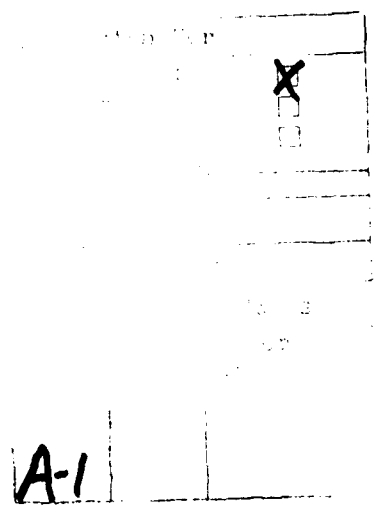
U. S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the

Deputy Chief of Staff for Personnel

EDGAR M. JOHNSON
Technical Director

WM. DARRYL HENDERSON
COL, IN
Commanding



A-1

DTIC
COPY
INSPECTED
2

This report, as submitted by the contractor, has been cleared for release to Defense Technical Information Center (DTIC) to comply with regulatory requirements. It has been given no primary distribution other than to DTIC and will be available only through DTIC or other reference services such as the National Technical Information Service (NTIS). The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARI Research Note 85-28	2. GOVT ACCESSION NO. AD-A163 062
	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* ARI V(INT)^2 Soldier-Machine Interface Demonstrator: Phase I Mid-Year Review	5. TYPE OF REPORT & PERIOD COVERED Interim Report May 1984-December 1984
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Azad M. Madni and Raymond C. Sidorsky	8. CONTRACT OR GRANT NUMBER(s) MDA 903-84-C-0219
9. PERFORMING ORGANIZATION NAME AND ADDRESS Perceptronics, Inc. 21111 Erwin Street Woodland Hills, CA 91367	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2Q263744A793
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Research Institute in the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600	12. REPORT DATE October 1985 13. NUMBER OF PAGES 88
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)* - -	15. SECURITY CLASS. *(of this report)* Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT *(of this Report)* Approved for public release; distribution unlimited	
17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)* - -	
18. SUPPLEMENTARY NOTES Raymond C. Sidorsky, contracting officer's representative	
19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)* Soldier-Machine Interface Expert Systems User Computer Interaction Human Factors Engineering Information Processing Models Armored Vehicle SMI V(INT)^2	
20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)* This research note is the mid-year report of a project designed to develop and evaluate a prototype "intelligent" soldier machine interface(SMI), for commanders of small combat units. The note showcases the ways in which applied expert system technology can be used to reduce the cognitive burden on combat commanders of the data-rich, highly stressful battlefield environment. The scenario developed to provide an early demonstration of some of the features of an "expert' enhanced SMI is a tank platoon movement-to-contact, in which an enemy force is ambushed.	

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

FOREWORD

The Battlefield Information Systems Technical Area of the Army Research Institute (ARI) is concerned with helping users and operators cope with the ever increasing complexity of the battlefield and automated systems by which they acquire, transmit, process, disseminate, and utilize information. Increased system complexity increases demands imposed on the human interacting with the machine. ARI's efforts in this area focus on human performance problems related to interactions with command and control centers and on issues of system design and development. Research is addressed to such areas as user-oriented systems, information management and display, decision support, and the impact of "high technology" on systems integration and utilization.

One area of special research interest involves the Soldier/Machine Interface. The ultimate aim of this area of research is to provide user-oriented functional specifications for a data management/display systems architecture of a generic SMI. That is, an SMI adaptable to multiple battlefield functional areas such as command/control, maneuver, armor, cavalry, artillery, combined arms, etc. The initial development is focused on increasing the operational effectiveness of commanders of small units, i.e., combat units that exchange fire with the enemy.

Research in the area of user-oriented systems is conducted as an in-house effort augmented through contracts with uniquely qualified organizations. The present effort was conducted in collaboration with personnel from Perceptronics, Inc., under contract MDA903-84-C-0219. The effort is responsive to requirements of Army Project 2Q263744A793, Human Performance Effectiveness and Simulation, and to special requirements of the U.S. Army Armor Center and School, Ft. Knox, Kentucky.

The following individuals contributed to the technical activities reported in this research note:

PERCEPTRONICS, INC.

Chu, Y.Y.
Fielding, M.
Levine, S.
Madni, A.M.
Samet, M.
Schwalm, N.
Scopp, R.

ANACAPA SCIENCES, INC.

Dyck, J.
Fuller, R.G.
Harris, D.H.
McCallum, M.C.
Rogers, S.P.

BOLT BERANEK AND NEWMAN, INC.

Pew, R.
Stevens, A.
Wilcox, B.

ARMY RESEARCH INSTITUTE

Sidorsky, R.C.

TABLE OF CONTENTS

Page

1. INTRODUCTION 1

   1.1 Overview 1
   1.2 Background 1
   1.3 Situational Context 3
   1.4 The Soldier-Machine Interface Concept 4
   1.5 Expert Rule-Based (ERB) Protocol Development 4

2. GENERAL FEATURES OF THE PROJECT 7

3. PHASE I ACTIVITIES 19
   Approach 21
   Accomplishments 22
   Task 1A: Task Analysis of Armor Operations 23
   Task 1B: Design Work Station 27
   Task 1C: Scenario Development 31
   Task 1D: Development of ERB Protocols 51
   Task 1E: Develop and Fabricate Demonstrator. 63

4. TECHNICAL SUMMARY 75

5. REFERENCES 83

1. INTRODUCTION

1.1 Overview

The primary objective of Phase 1 of the current effort is to develop and evaluate a prototype "intelligent" soldier-machine interface (SMI) for commanders of small combat units. The general thrust is toward showcasing the ways that applied expert system technology can be used to reduce the tremendous cognitive burden imposed om combat commanders in the data-rich, highly stressful battlefield environment. The scenario developed to provide an early demonstration of some features of an "expert" enhanced SMI is a tank platoon movement-to-contact in which an ambush of an enemy force is executed. Expert protocols that manage/display selected information extracted from a digitized map data base are featured in this initial version.

1.2 Background

The need to develop and test innovative soldier-machine interface (SMI) unit commanders (company and below) is recognized by HQDA, TRADOC, and DARCOM. One focal point for R&D activities to meet this need is the $V(INT)^2$ (Vehicle Integrated Intelligence) concept. $V(INT)^2$ is an outgrowth of a recommendation made by the Army Science Board (summary 1981) and suggestions made by GEN Blanchard, GEN Otis, and others. In a parallel development, the Armored Vehicle Science and Technology Program Advisory Council has established a technology base initiated to provide "the system architecture for the total integration of ground vehicle electronic (Vetronic) systems within the integrated battlefield." The need for an optimum and standardized SMI is recognized as a prime requisite for improved system effectiveness within the Vetronics structure.

A major goal of the $V(INT)^2$ (and Vetronics) program is to provide small unit commanders (e.g., a tank platoon leader) with information products derived from "high technology." These information products now provide the data for computerized data management/display systems that supply large unit headquarters with real time information regarding friendly and enemy forces, terrain, and other aspects of tactical operations. However, because of recent advances in sensor, communication, and data processing technologies, battlefield data is produced at

volumes and rates that exceed the capacity of a small unit commander to absorb it. The solution is to provide data management/display systems that will tailor the amount, format, and level of detail of information to: (1) the needs of commanders at various echelons, and (2) the changing needs of a commander as the tactical situation develops.

A key element of a successful data management/display system is a properly designed SMI through which information is transferred by the commander to and from the machine (computer). The primary objective of the current effort is to create a research test bed for use in developing such an optimum interface. The purpose of this test bed, hereafter referred to as the ARI V(INT)^2 SMI Demonstrator, is to demonstrate a data management/display system that utilizes Expert Rule-Based (ERB) protocols to control the input/output of information. As used here, the term Expert Rule-Based protocols refers to any of the various types of interactive data management or decision aiding processes based on the application of artificial intelligence techniques. The purpose of the ERB protocols is to take advantage of the high rate of acquisition, transmission, and processing of battlefield data available via current electronic technology. Timely access to unit-relevant information will provide a force multiplier to small unit commanders in the future AirLand Battle and AirLand Battle 2000 environments.

The ARI V(INT)^2 SMI Demonstrator will provide a test bed for evaluating alternative approaches to incorporating flat panel displays, voice input of commands, interactive input/display screens, multi-function control panels, synthetic voice alarms/instructions, Expert Rule-Based protocols, decision aids, and other candidate applications of "high technology" to the Soldier/Machine Interface (SMI). By providing a dynamic, graphical interface along with integrated voice inputs/outputs and multifunction control panels, the ARI V(INT)^2 Demonstrator will enable measurement, in realistic man-in-the-loop tests, of the increase in operational effectiveness that can be expected from the innovative data display/management concepts envisioned by the Army, DoD, and the scientific/industrial communities. These tests will provide objective data based on user performance, reaction, and acceptance, that will enable systems designers and proponents to assess the potential improvements in operational effectiveness that could result from the incorporation of candidate hardware/software features in the

soldier/machine interface of future tactical systems. Initial efforts will focus on tank operations. However, the language goal is to develop a simple user-tested SMI architecture adaptable to the needs of small unit commanders of a broad spectrum of combat and combat support elements (infantry, artillery, armor, cavalry, combined arms, etc.)

1.3 Situational Context

It is D+8, and the AirLand Force Charlie (ALF Charlie) is reorganizing in the vicinity of Treischfeld (NB 630233). Fighting has been fierce and although the enemy's attack has been broken, own force resources are limited. Recent activity indicates that the command and control structure of the enemy has disintegrated. Battle tactics are not following doctrine. Small unit engagements are common as isolated enemy forces attempt to relocate parent units.

VISTA assets have just reported a communications intercept of an enemy radio transmission emanating from the vicinity of Morsberg (hill 466, vic NB 611186). The caller identified his force as four T-88 tanks and two infantry fighting vehicles, and their objective as the city of Geisa (vic NB 673187).

A platoon from Bravo Company of the 1st Battalion, Regiment 3, AFL Charlie, is located on the outer perimeter of the ALF's current position (vic NV 651228). This platoon is equipped with V(INT)^2 and the Tank Platoon Leader (TPL) has just confirmed his unit location, mission status, and readiness.

The next major concern of the TPL is to determine where an ambush operation can be successfully performed given the current path of the enemy, the most likely/expected enemy behavior, and the prevailing situational constraints (e.g., terrain, enemy strength, expected speeds, direction of movement, expected terrain trafficability for the enemy and friendly unit, and expected enemy tactics). If a specific location for ambush is found, the TPL undertakes the ambush operation. If no ambush is found, given specific situational constraints and enemy capabilities, the TPL has to make a rapid assessment whether ambush operations can be abandoned. If it turns out that an ambush operation **has** to be performed, then the TPL may systematically relax constraints by, for example, increasing the area in which ambush operations are to be performed or selecting a more detailed map for analysis until a viable ambush point is identifiable.

1.4 The Soldier-Machine Interface Concept

The initial demonstration of the soldier-machine interface will feature a multiwindow display along with the following input media:

- Voice
- Graphics tablet
- Joystick/Handgrip devices
- "Soft" function keys (e.g., 5 x 4 bank of "smart" switches from micro-switch)

Four separate displays or four display windows created on a single display will be configured to present the following information:

(1) Command Display for viewing textual alert/alarm messages or composing formatted messages (for example, tactical message viewing/composition and selective call-up of information related to the objective, operation mode, or the target).

(2) World View Display consisting of external sensor information overlayed on map background. The area covered in these displays will be compatible with battalion-wide or brigade-wide levels of interest.

(3) Close-in View Display consisting of map background covering the immediate area of interest to the platoon leader (3 km) with graphic overlays consisting of battlefield information such as ambush location, immediate avenues of approach, cover and concealment, and trafficability, etc.

(4) Computer-Generated Imagery (CGI) or Status Display (no video) showing own vehicle and platoon status or tactical situation (at various levels of abstraction) in terms of intercept geometrics, and windows of opportunity (present and predicted) for ambush operations.

1.5 Expert Rule-Based (ERB) Protocol Development

The tactical scenario segment selected for the inital demonstration offers a few distinct situations for ERB protocol development. These include determining the ambush point, finding an intercept path to the ambush point, and selectively relaxing constraints to find one or more ambush points if none were found on the

initial pass. The ERB protocols will be supported by digital terrain data files and inputs from scenario generator/event sequencer. The terrain (elevation and feature) analysis routines will first be established to generate processed tables of (1) line of sight, (2) intervisibility, and (3) trafficability for the given 10 x 10 km area. Time-varying object data files including target, own vehicle profile, objectives, and friendly and enemy tactics will be constructed. In support of the tactical situation display related to ambush mode protocol, the subfunctions (rules or algorithms) shown in Table 1 will be derived.

TABLE 1

SUBFUNCTIONS OF
AMBUSH MODE PROTOCOL

- Projection of friendly and enemy routes/trajectories
- Presentation and updates of masking and concealment
- Projection of interception points/paths
- Identification of hull defilade positions
- Prediction of the line-of-sight
- Projection of target servicing opportunity window
- Evaluation of constraints/criteria relaxation

2. GENERAL FEATURES OF THE PROJECT

V(INT)^2 CONCEPT

- Close combat vehicle commander's interface with:
  - -- Vehicle's modular subsystems
  - -- Battalion--outside world
- Focus on providing information and intelligence
  - -- At the appropriate time and place
  - -- In the proper sequence, format, and priority
- Onboard computer employs AI software packages based on expert systems technology

V(INT)^2 PROGRAM OBJECTIVES

- DEVELOPMENT OF:
  - -- V(INT)^2 SMI demonstration facility and prototype work station
  - -- A scenario that encompasses simulated inputs from downlinked data sources
  - -- Expert rule-based (ERB) protocols for information management and decision aiding
  - -- Human-related performance measures that impact battlefield effectiveness
  - -- Measures for assessing impact of ERB protocol-augmented human performance on battlefield outcomes
  - -- Functional specifications for operational data display/management system

- EXPLOITATION OF:
  - -- "Force Multiplier" potential of high technology

THE DRIVING TECHNOLOGIES

- APPLIED AI AND EXPERT SYSTEMS TECHNOLOGY
  - -- Expert rule-based protocols for data fusion, manipulation, display
  - -- Intelligent interfaces

- VOICE INPUT/OUTPUT AND PROGRAMMABLE SMI CONTROL PANEL
  - -- Voice recognition/synthesis
  - -- "Soft" function keys/touch panel, other

- INTERACTIVE VIDEODISC
  - -- Background for graphics overlay
  - -- Micro-controlled

- COMPUTER GENERATED IMAGERY AND HIGH RESOLUTION GRAPHICS
  - -- Color
  - - Multiple windows
  - -- Line-of-sight, trafficability, intervisibility

DEMONSTRATION FACILITY AND PROTOTYPE WORK STATION

- From bench system to functional prototype
- Emphasis on selective fidelity
- Focus on user involvement/input
- Reconfigurable architecture
- Evaluation of alternative soldier-machine interface option, expert rule-based protocols, and display layouts

FEATURES OF THE APPROACH

- Human factors analyses and studies in parallel with prototype development
- Operational fixed prototype of the SMI work station
- Added task to guarantee success of our technology transfer plan
- Adoption of an initial "strawman" prototype design

THE SCENARIO: SETTING AND FUTURE CAPABILITIES

- Based on AirLand Battle 2000/Army 21 environment
- Simulated communications links to VISTA/DC^{3}I
- Simulated inputs from commander's independent thermal viewer (CITV)
- Simulated inputs from remotely-piloted vehicles equipped with FLIR and low light level TV

BACKGROUND: GENERAL SITUATION

- HOSTILITIES INITIATED:
  - -- Fulda Gap, West Germany
  - -- U.S. mission--security operation

- RATIONALE:
  - -- Area of U.S. Army interest
  - -- Security operation allows multi-mission possibilities
  - -- Digitized Fulda Gap terrain is readily available

SPECIFIC SITUATION

- UNIT LEVEL:
  - -- Platoon (4 tanks)
- MISSION:
  - -- Move to a preestablished blocking position
- SITUATION:
  - -- Precipitates engagement
  - -- Engagement facilitates ambush opportunity
- RATIONALE:
  - -- Manageable number of participants
  - -- Realistic mission assignment
  - -- Requires action
  - -- Identifies key events
  - -- Isolates required activities
  - -- Suggests display type(s) and associated information requirement(s)
  - -- Indicates potential AI/expert systems application area

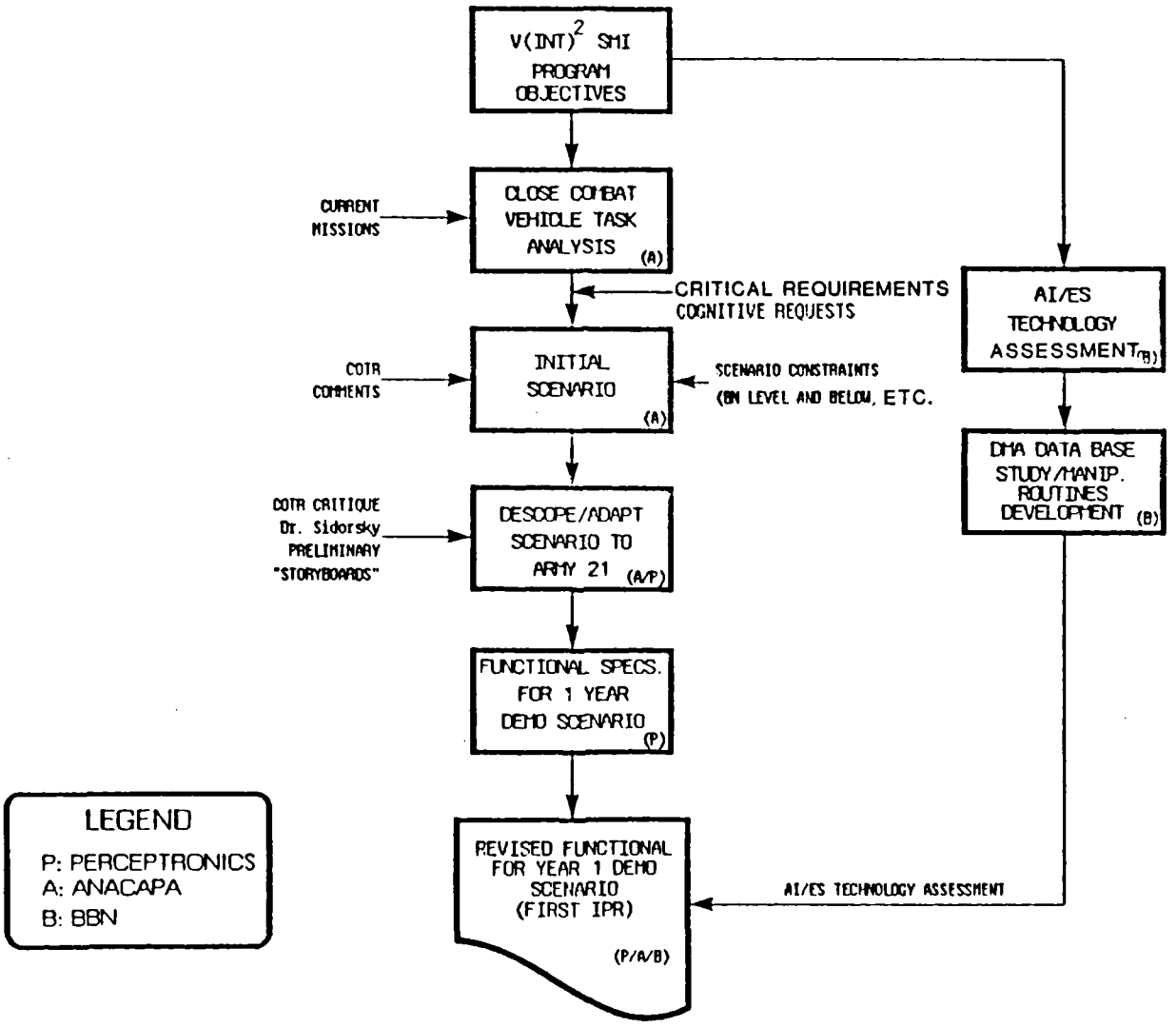
PROGRAM PRODUCTS

- CONCEPTS, TECHNOLOGIES, AND SYSTEMS THAT WILL PROVIDE:
  - -- A "force multiplier" on the battlefield
  - -- **Through** performance enhancement of the soldier working **with** his equipment **in** the unit

- SPECIFICATIONS FOR A DATA DISPLAY/MANAGEMENT ARCHITECTURE
  - -- Utilizing state-of-the-art in applied AI and man-machine interface technology
  - -- Adaptable to multiple battlefield applications

3. PHASE I ACTIVITIES

PHASE I APPROACH



PHASE I ACCOMPLISHMENTS

TASK 1A

- C^2 information requirements/task analyses completed
- Critical cognitive tasks identified

TASK 1B

- Prototype work station "mockup" designed and fabricated

TASK 1C

- Detailed demonstration scenario analyzed
- Man-machine interactions identified
- Refinements/recommendations summarized
- Opportunities for ERB protocol development identified
- $V(INT)^2$ SMI architecture for demonstration scenario specified

TASK 1D

- ERB support software partially developed
- DMA data base manipulation routines partially completed

TASK 1E

- Voice (i.e., VOTAN), PDP switches, and Beetle cursor controller integrated with symbolics
- Voice, PDP switches, and Beetle cursor controller demonstrable with scenario script

TASK 1F

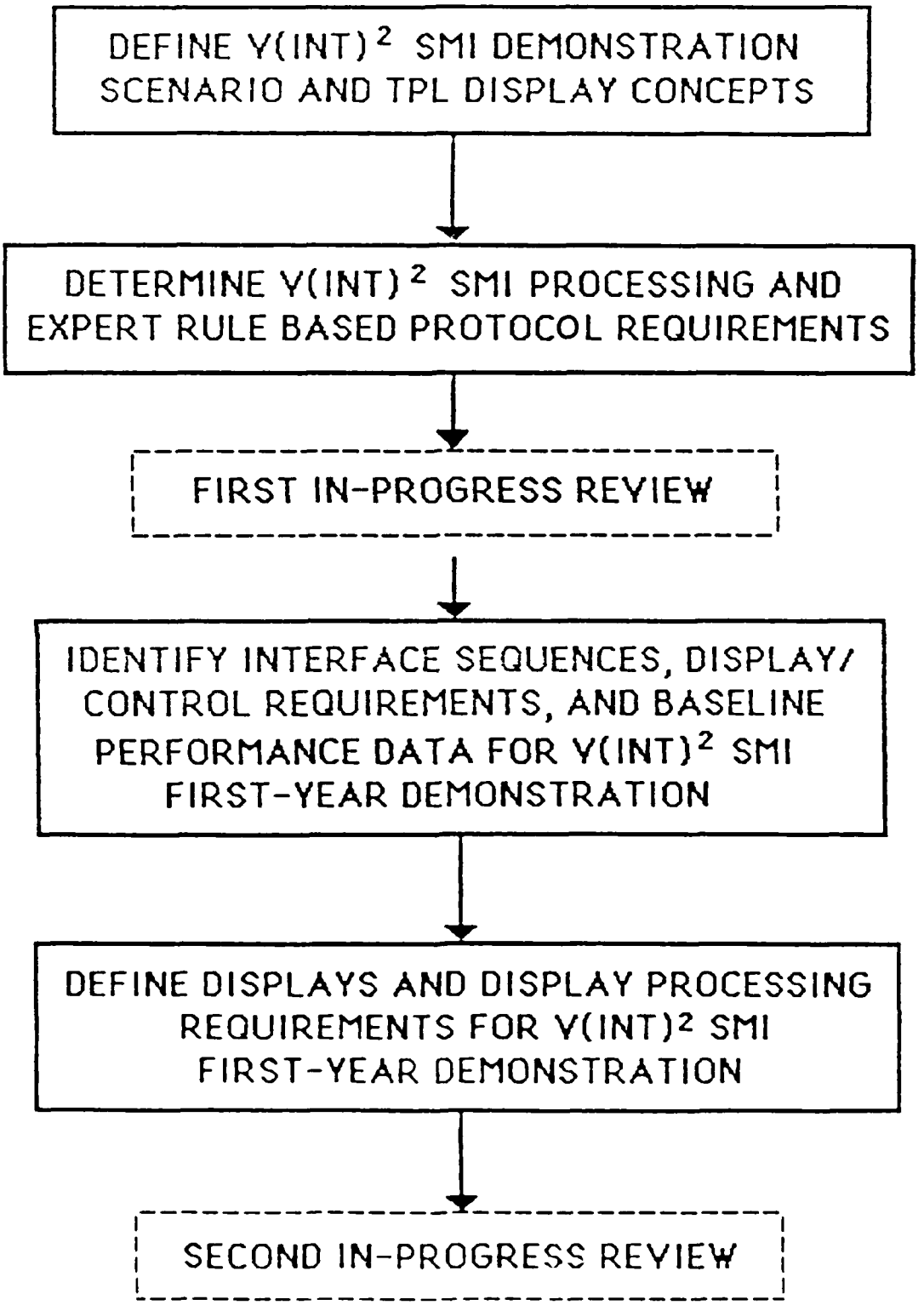
- Performance-based approach for demonstrator evaluation partially defined

TASK 1G

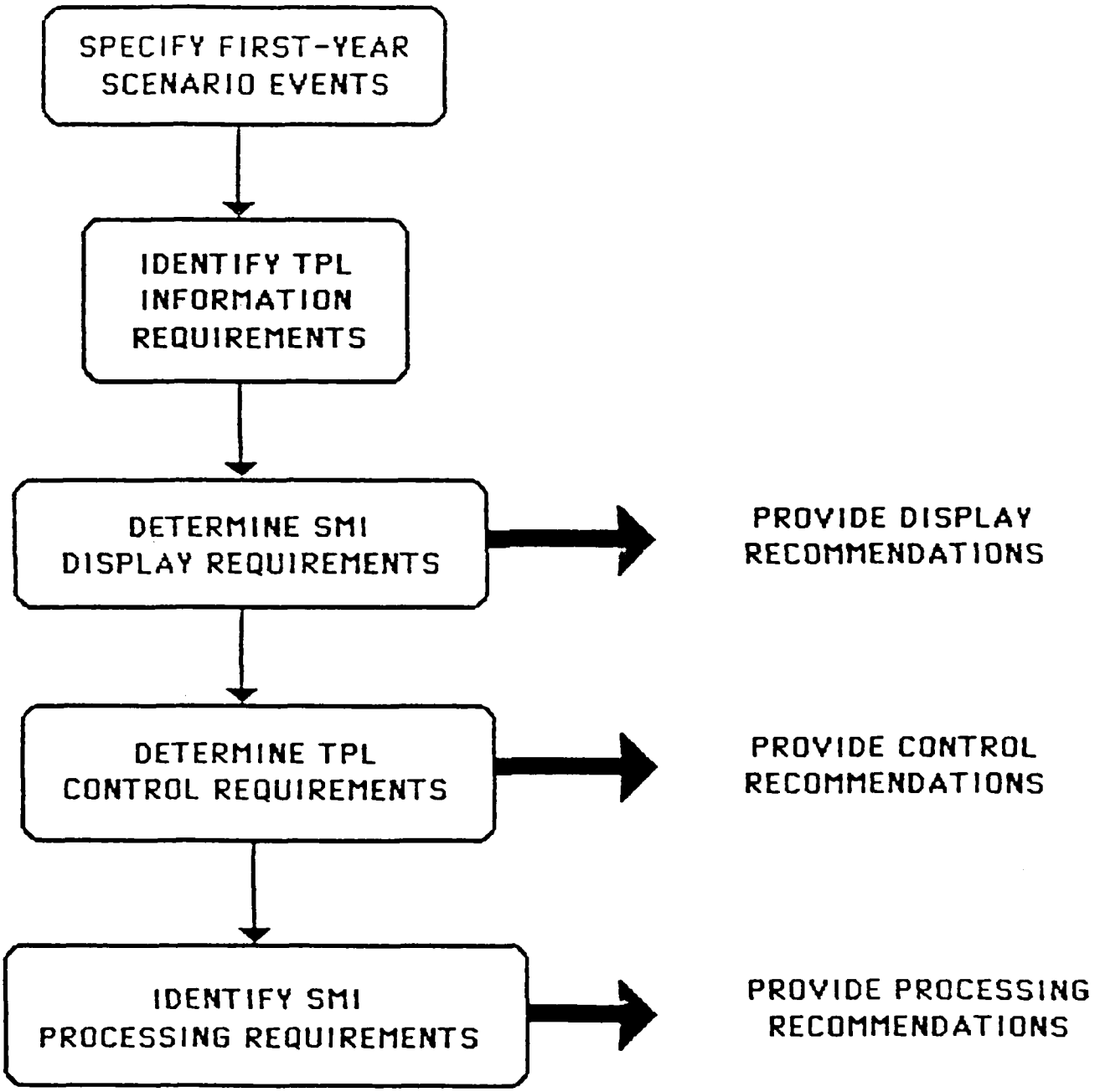
- Demonstration script reconciled with "big picture"
- User community involvement initiated for successful technology transfer

TASK 1A: Task Analysis of Armor Operations

ANACAPA ACTIVITIES



ANACAPA FIRST-YEAR DEMONSTRATION SCENARIO DEVELOPMENT STRATEGY



TPL INTERFACE SEQUENCES FOR SMI FIRST-YEAR DEMONSTRATION

1. Enter or modify information on **LOCAL CONDITIONS**

2. Acknowledge receipt of **FRAGO** from company commander designating target and specifying intercept action

3. Put system in **INTERCEPT MODE**

4. Assess **TARGET SITUATION**

5. Project probable **TARGET ROUTE**

6. Select **TARGET ROUTE INTERCEPTION SEGMENT**

7. Select **AMBUSH SITE** from possible alternatives

8. Select **OPTIMUM ROUTE** to ambush site

9. Project **TARGET SERVICING WINDOW**

10. Issue **FRAGO** to platoon for movement to ambush site

11. **ADVANCE** to ambush site

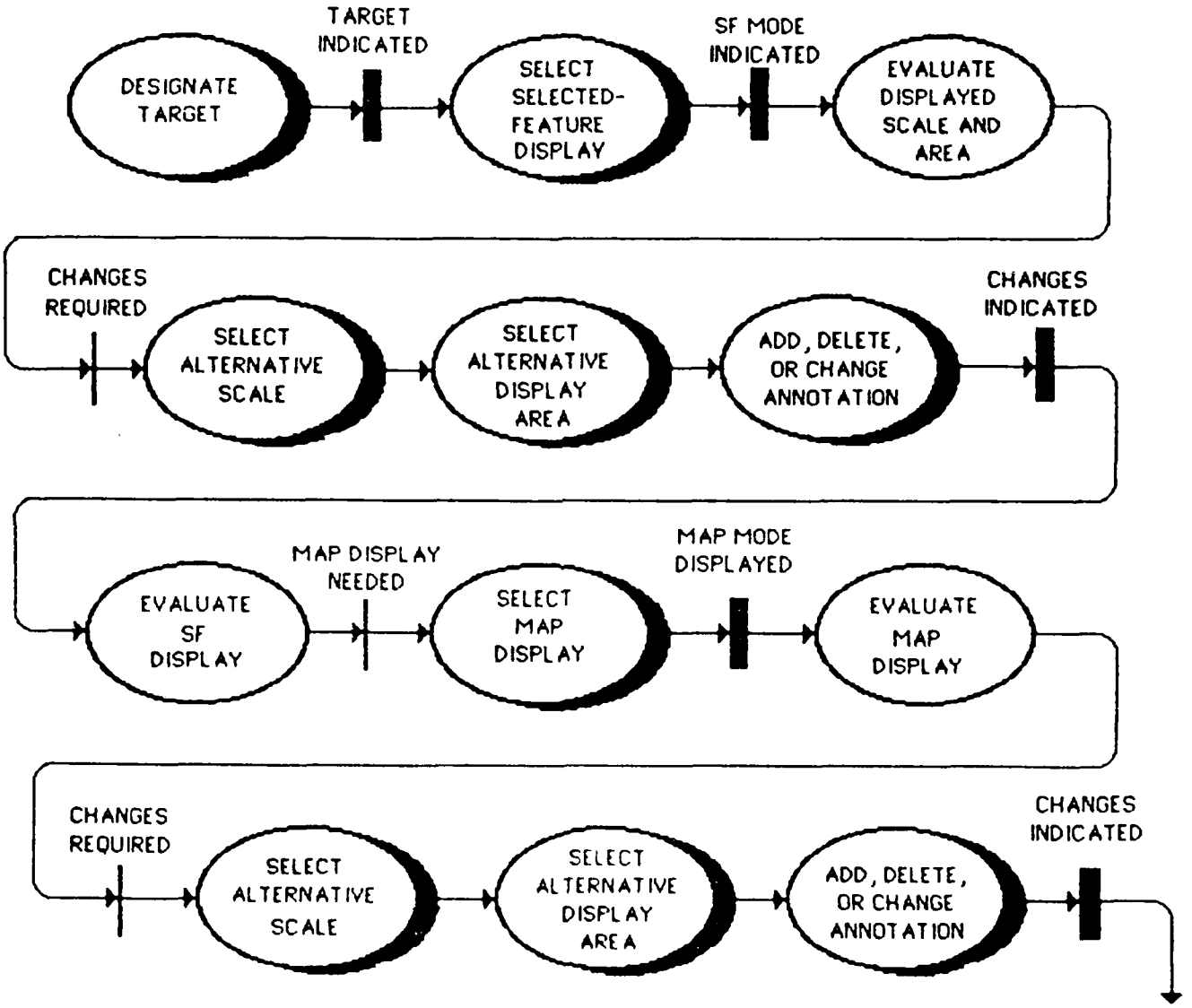
12. Determine **FIRING SECTOR** for the platoon

13. Issue **FRAGO** specifying **FIRING SECTOR** for the platoon

14. Issue **FIRE COMMAND** when the target enters the target servicing window

EXAMPLE OF SEQUENCE ANALYSIS

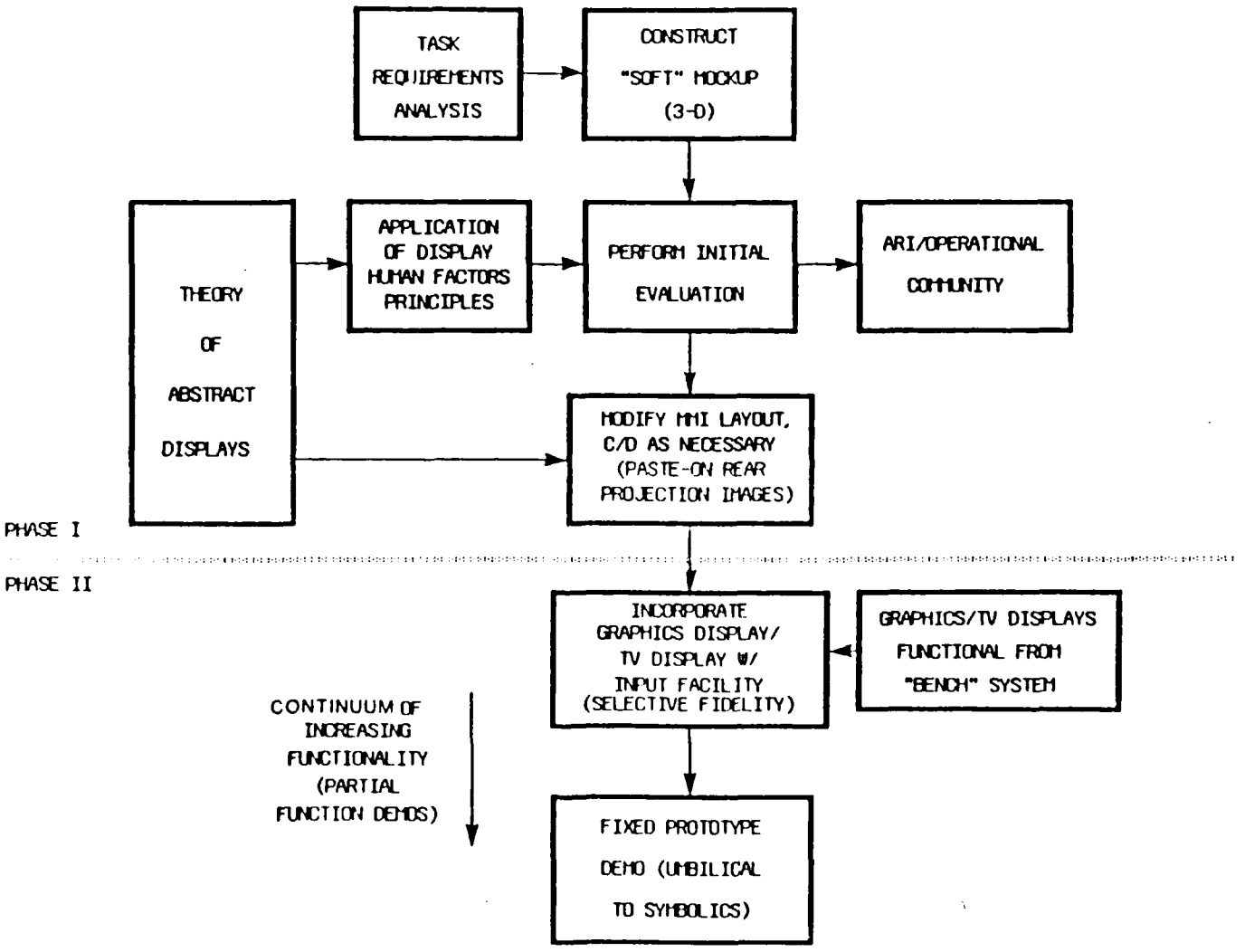
Sequence 4: Assess Target Situation



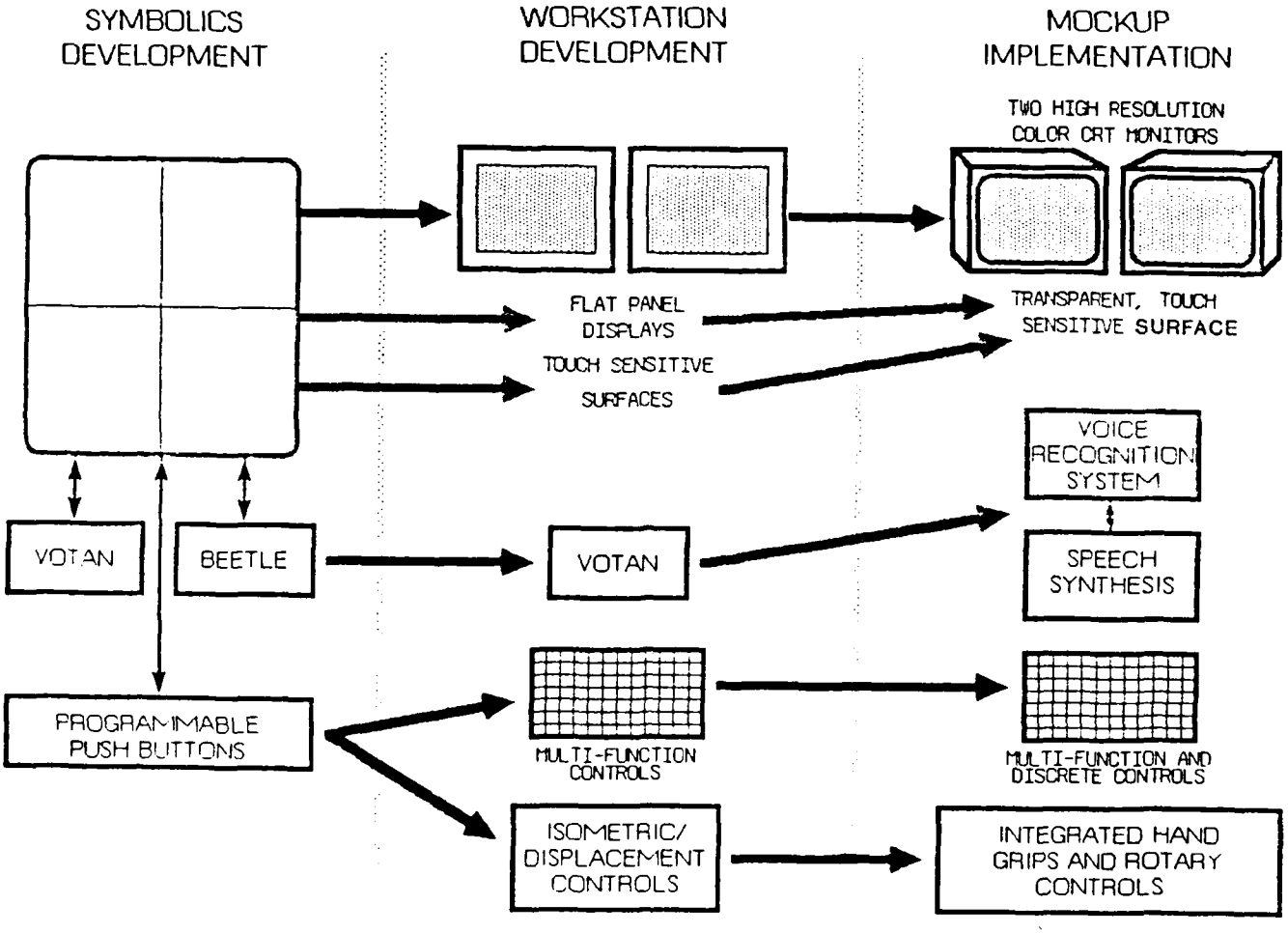
DESIGN WORK STATION

- MOCKUP CONSTRUCTION
- MOCKUP DEVELOPMENT
- CONTROL AND DISPLAY HARDWARE CONFIGURATION
- SYSTEM INTEGRATION

MOCKUP DEVELOPMENT



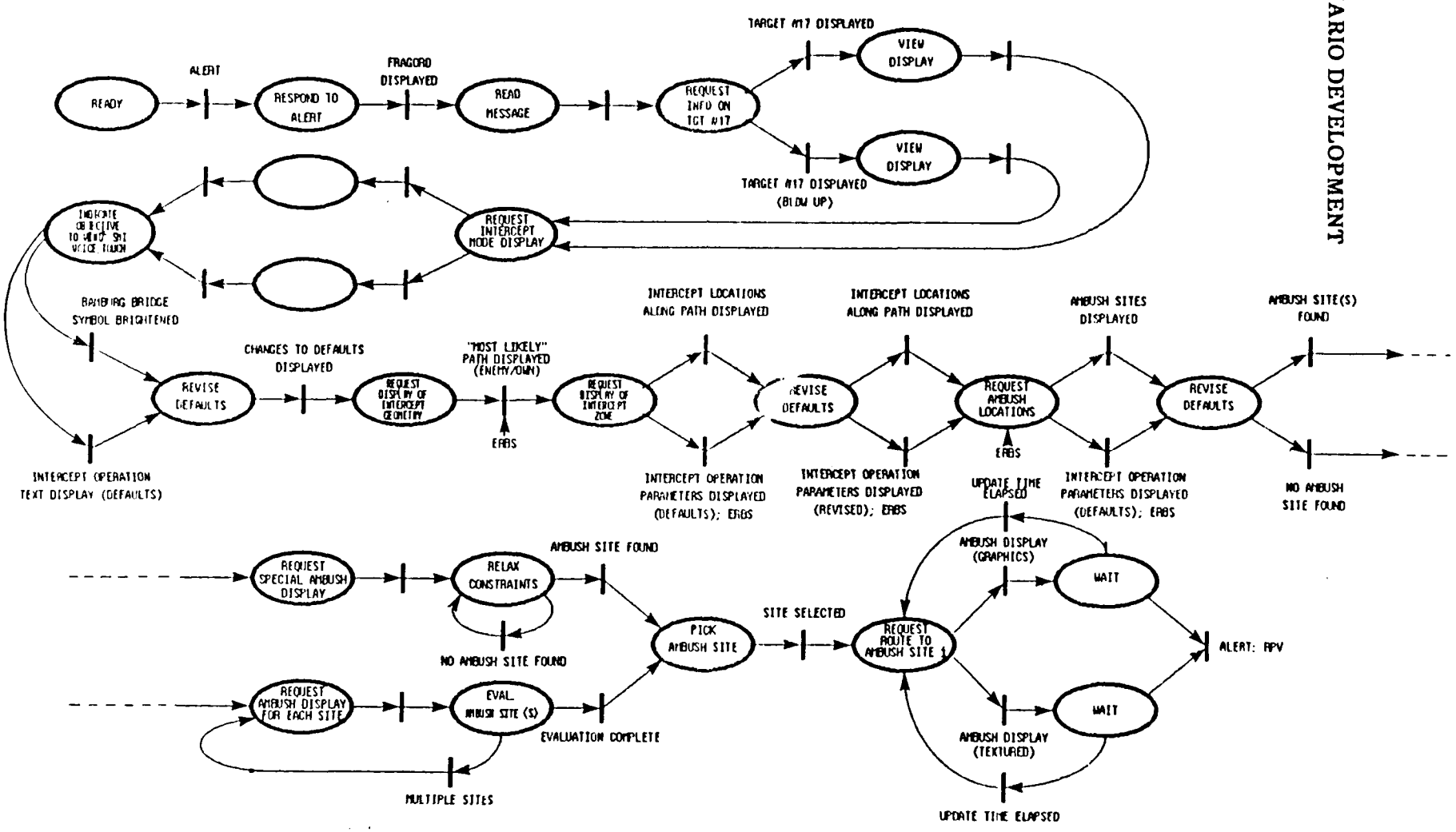
CONTROL AND DISPLAY HARDWARE CONFIGURATION



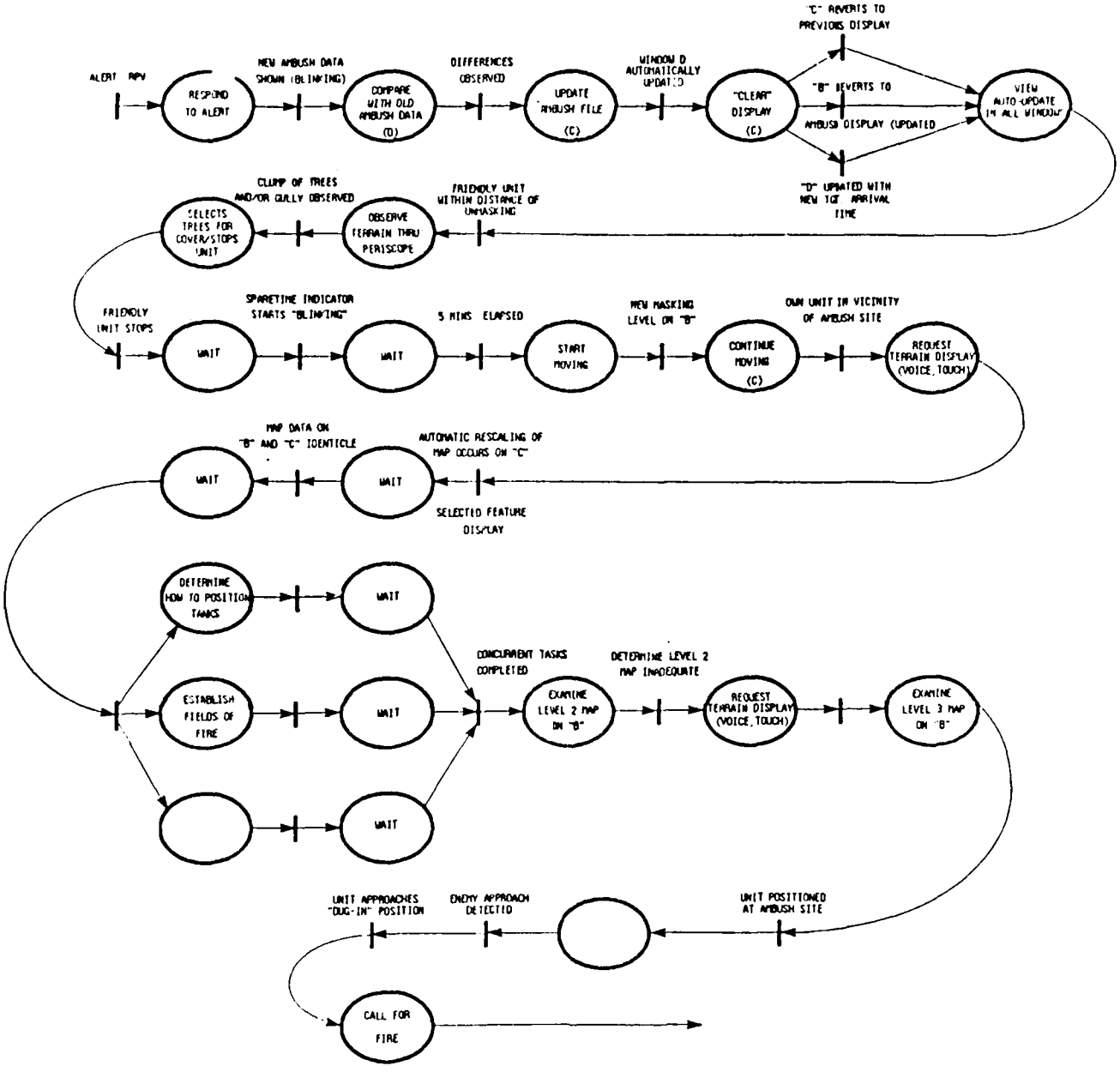
SYMBOLICS INTERFACE OPTIONS

- OPTIONS
  - SERIAL
  - MULTIBUS
- CURRENT CONFIGURATION HAS 3 SERIAL (1 USED BY KEYBOARD)
- NEW BOARD WILL HAVE 4 SERIAL AND 1 MULTIBUS

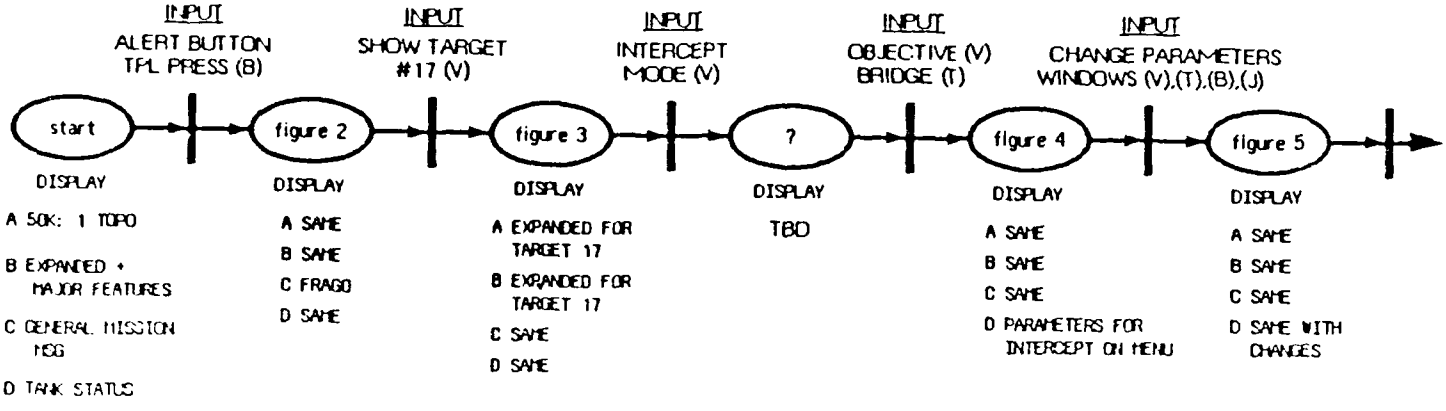
PHASE I DEMO SCENARIO ACTIVITY SEQUENCE (FROM TPL VIEWPOINT)

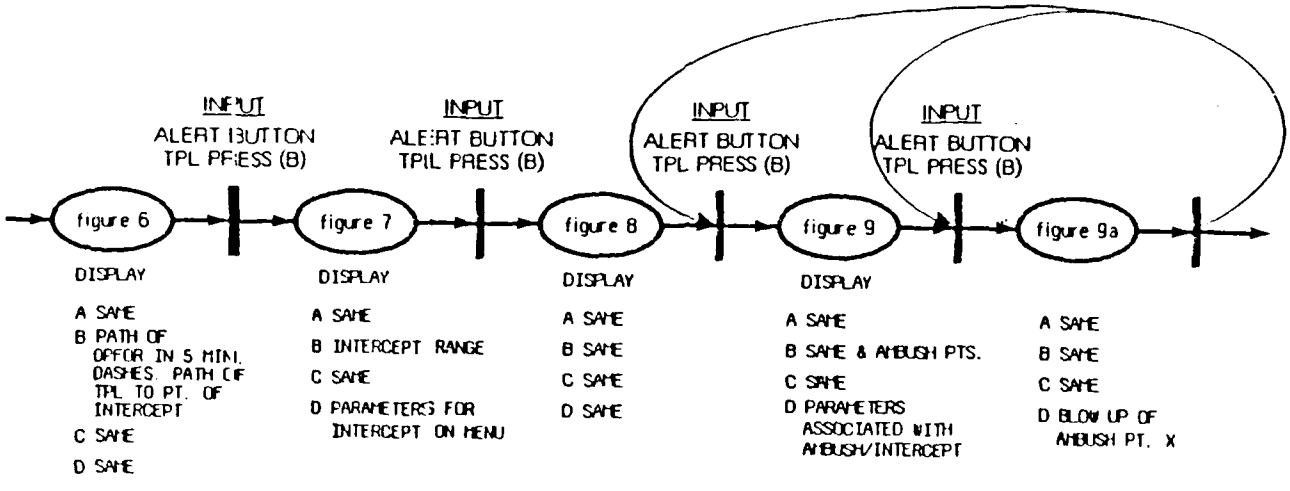


PHASE I DEMO SCENARIO ACTIVITY SEQUENCE (FROM TPL VIEWPOINT) (CONT'D)

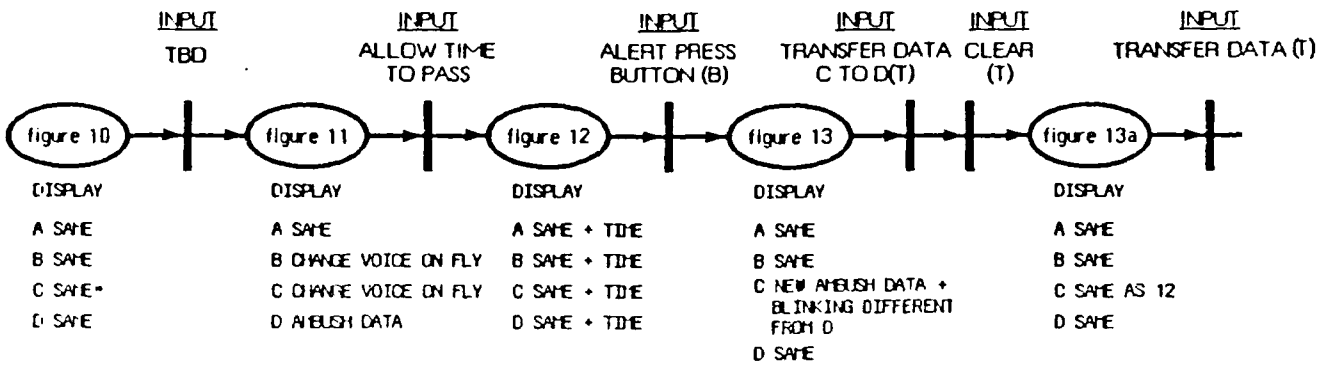


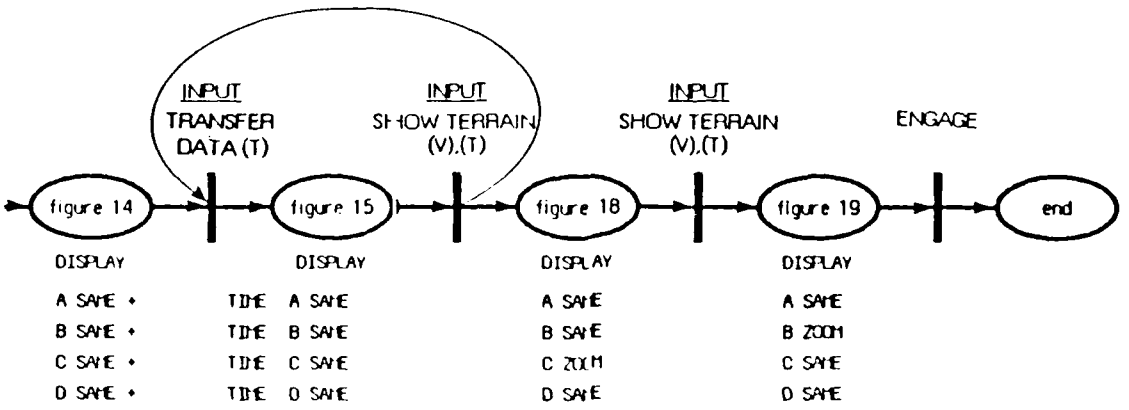
V(INT)^2 STATE MACHINE





V(INT)^2 STATE MACHINE (CONT'D)





FIRST YEAR DEMONSTRATION

ENEMY(GENERAL)

- OFFENSIVE BROKEN
- C^3 DISRUPTED
- TACTICS NOT FOLLOWING DOCTRINE
- UNITS SCATTERED
- ATTEMPTING TO RELOCATE OWN FORCES

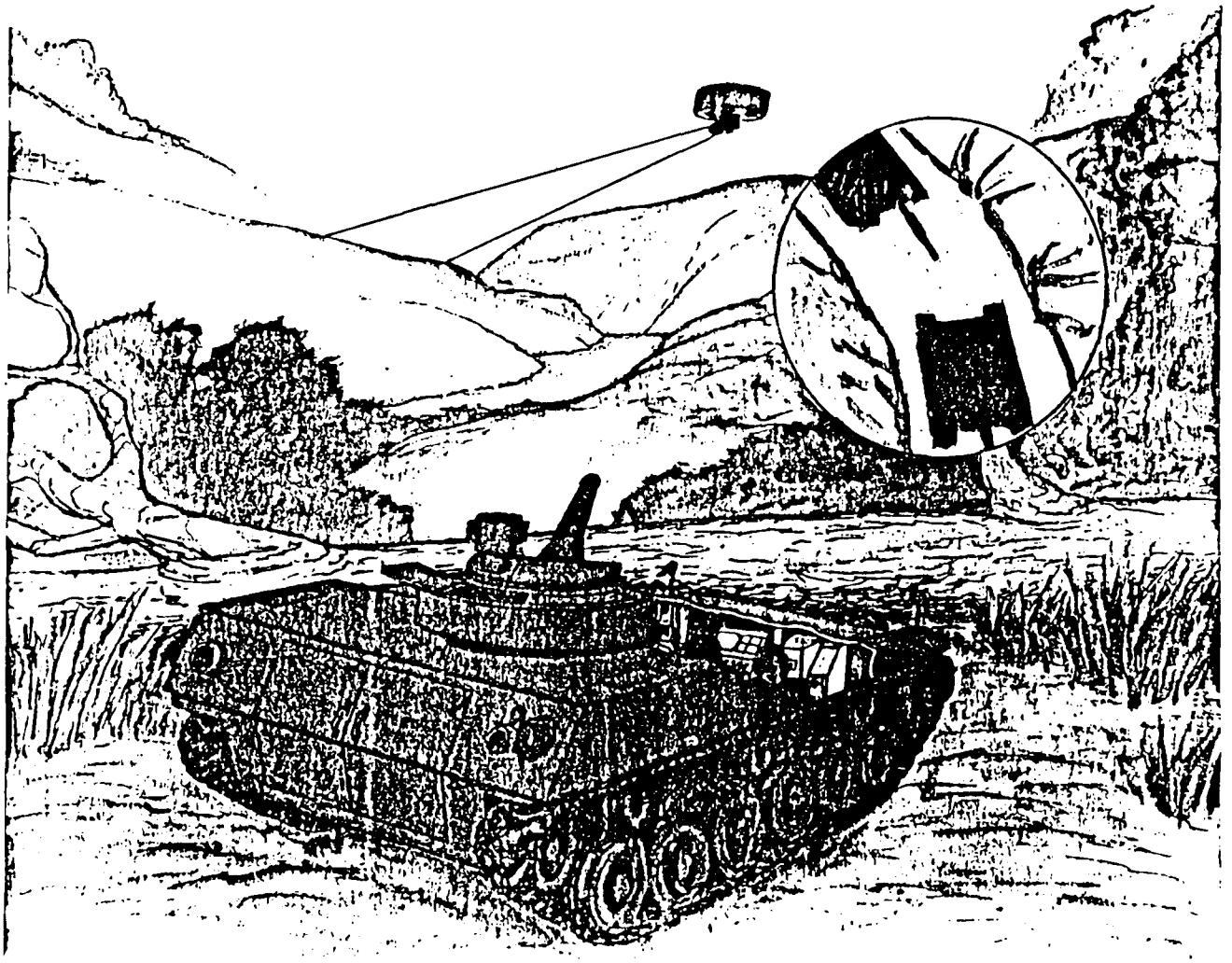
ENEMY(SPECIFIC)

- REMNANT OF A LARGER UNIT
- 4X T88 AND 2X BMPX LOCATED VIC RASDORF BY VISTA COMINT
- PLAIN VOICE TRANSMISSION WITH CALLER IDENTIFYING GEISA (VIC NB 673 187) AS OBJECTIVE

FRIENDLY

- **OWN FORCES ARE LIMITED**
- **ECONOMY OF FORCE PRIMARY TO OWN FORCE ALLOCATION DECISIONS**
- **VISTA ASSETS OPERATIONAL**
- **$V(INT)^2$ SUPPORT AVAILABLE TO THE TANK PLATOON UNIT LEVEL**
- **TANK PLATOONS IN FUTURE DOCTRINE MAY CONDUCT PURSUIT / INTERCEPT AND AMBUSH OPERATIONS**

SCENARIO



V(INT)^2 SCENARIO

- SPECIAL SITUATION:

1. VISTA ASSETS HAVE REPORTED ELEMENTS OF **AN ENEMY FORCE** MOVING ACROSS THE INTERNATIONAL BORDER

2. COMINT ASSETS INDICATE THE ENEMY FORCE MISSION IS TO SECURE A BRIDGE CROSSING

3. UPDATES FROM VISTA ASSETS PROVIDE STRENGTH, COMPOSITION, PROBABLE ROUTE AND MOVEMENT SPEED OF ENEMY FORCE

V(INT)^2 SCENARIO (CONT'D)

- SPECIAL SITUATION: (CONTINUED)
  - FRIENDLY ELEMENT FOR FIRST–YEAR DEMONSTRATION IS PLATOON–SIZED
  - FRIENDLY MISSION IS TO ENGAGE THE ENEMY FORCE PRIOR TO THE ENEMY REACHING ITS OBJECTIVE (AMBUSH)
  - NO SUPPORTING ARMS WILL BE EMPLOYED IN THE FIRST–YEAR DEMONSTRATION
  - ADVANCES BY FRIENDLY AND ENEMY WILL BE AXIS–LIMITED (ONE AXIS)
  - INITIAL POINTS, OBJECTIVE AND MISSION WILL REMAIN THE SAME FOR THE FIRST–YEAR DEMONSTRATION
  - SEE ARI RESEARCH NOTE 85–27 FOR DETAILED DESCRIPTION OF THE "AMBUSH" SCENARIO

TERRAIN SOFTWARE SOURCES

- BVGS/DOG – CAORA
- IMPS – AVRADA / HARRIS
- TERRAIN NAVIGATION – SANDIA / TACOM / VICOM
- AUTOMATIC TERRAIN ANALYSIS – ETL
- ROUTE PLANNING – TAU
- AUTONOMOUS VEHICLE – JPL
- ROUTE PLANNING – HUGHES
- ROUTE PLANNING – FMC

TERRAIN DATA SW/HW SOURCE EVALUATION

	MATURITY	AVAILABILITY ACCESSIBILITY	PROBLEM DOMAIN	ALGORITHM APPLICABILITY	HW / SW COMPATIBILITY	DATA BASE COMPATIBILITY
BVGS/DOG (CAORA)	X	X	GROUND TRAINING	X	PERKIN-ELMER SIGNAL 9 FORTRAN	X
IMPS (AVRADA / HARRIS)	X	PARTIALLY	AIR	X	VAX FORTRAN	DLMS
ROUTE PLANNING ALGORITHMS (TALL)	X	PARTIALLY	AIR & GROUND	X	PDP 11 FORTRAN	ART BASS LEVEL I
ROUTE PLANNING ALGORITHMS (HUGHES)	X	PARTIALLY	AIR & GROUND	X	VAX FORTRAN	ART BASS LEVEL I
(SANDIA / TACOM / VICOM)	-					
AUTONOMOUS TERRAIN ANALYSIS (ETL)	-					
AUTONOMOUS VEHICLE (JPL)	-					

AVAILABLE ALGORITHMS/FUNCTIONS BASED ON DIGITAL DATA BASE

- LINE OF SIGHT INTERVISIBILITY
- COVER / CONCEALMENT
- PERSPECTIVE VIEWS
- TRAFFICABILITY
- DEFILADE CALCULATION
- LOCAL MAPPING — SELECTED FEATURES
- SITUATIONAL ASSESSOR — GOAL, OBSTACLE KEY TERRAIN
  (EXTERNAL) VARIBLE CRITERIA EVALUATION
- SITUATION ASSESSOR — VEHICLE STATUS
  (INTERNAL)
- SITUATION ASSESSOR — ENEMY DIRECTION SPEED
  (TACTICAL GAME) PROJECTED ROUTE
- ROUTE PROJECTION
- ROUTE PLANNING / NAVIGATION

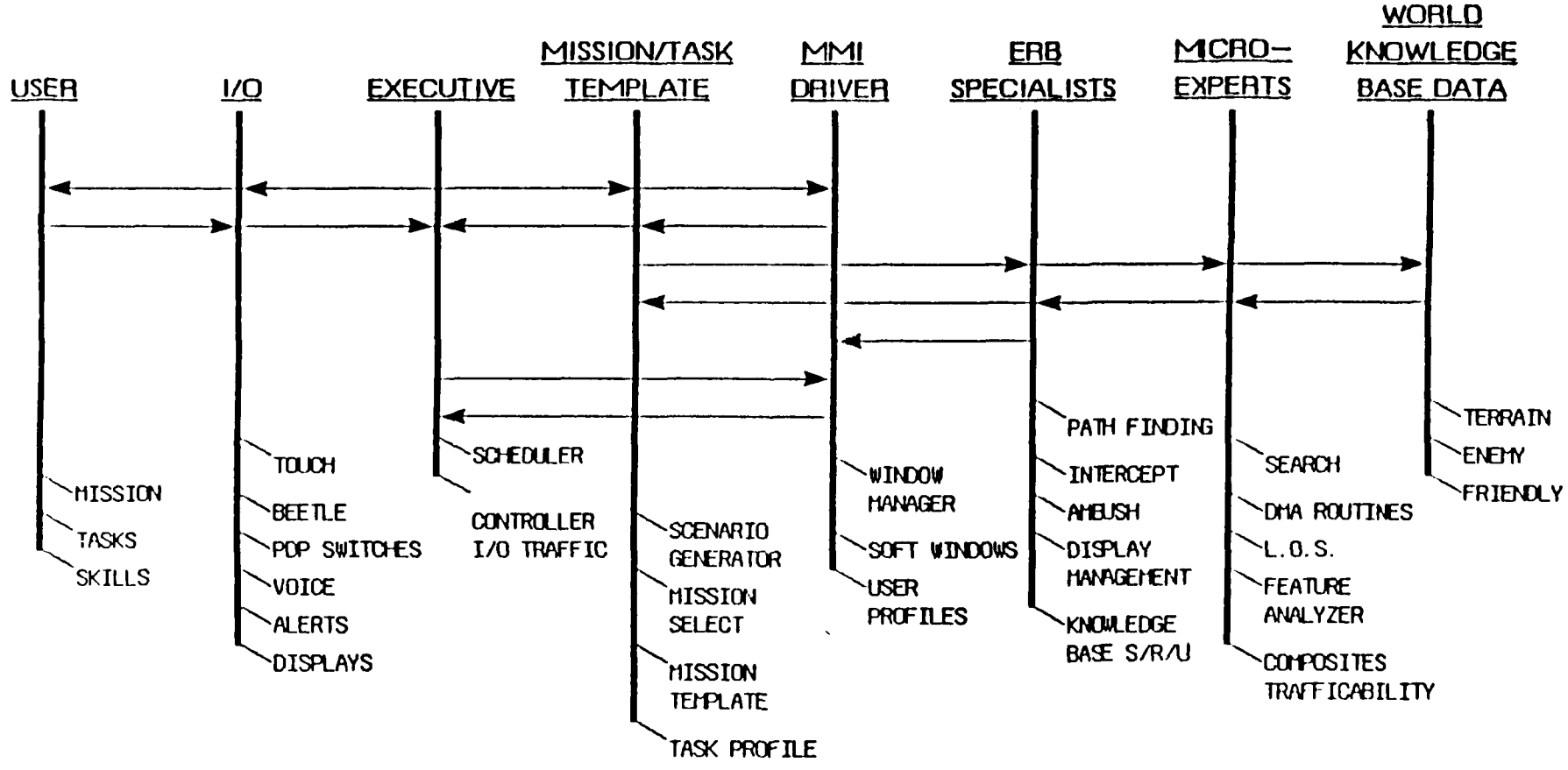
ROUTE PLANNING CAPABILITIES

- INITIALIZE ROUTE PLANNING PHASE
- INTERACTIVE ROUTE PLANNING PHASE
  - ENTER INITIAL AND TARGET POINTS BY POSITION CURSOR ON TOPO MAP
  - ENTER INTERMEDIATE ROUTE POINTS
  - DISPLAY POTENTIAL ROUTE CONSTRAINTS
  - ENTER OTHER ROUTE CONSTRAINTS (E.G. INTERVISIBILITY, COVER, CONCEALMENT, COMM. RADIO DEVICE POSITIONS
  - COMPUTE & DISPLAY ROUTE AS OVERLAY
  - WITH ESTIMATED TRAVEL TIME, POTENTIAL CHECK POINTS
- SELECTED ROUTE EVALUATION
  - VERIFY ROUTE – OTHER ANALYSIS ALGORITH MS
    1. SELECTIVELY PLOT INTERVISIBILITY FANS
    2. SELECTIVELY PLOT COVER CONCEALMENT
    3. SELECTIVELY DISPLAY PERSPECTIVE VIEWS
- EDIT ROUTE – ON SEGMENTS OF ROUTE; SELECT, ROUTE CONNECTION & SMOOTHING

ASSESSMENT OF DMA DATA MANIPULATION ALGORITHMS

- SOFTWARE/TOOLS SURVEYED CANNOT EASILY FIT IN THE SYMBOLICS' DEVELOPMENT ENVIRONMENT
- CURRENT SOFTWARE/TOOLS WILL BECOME OBSOLETE IN TWO YEARS
- EXISTING SOFTWARE/TOOLS OFFER ONLY LIMITED FUNCTIONS REQUIRING COMPLEX CALCULATIONS AND EXTENSIVE SOFTWARE SUPPORT
- STATE—OF—THE—ART DEVELOPMENT HAS MOVED TO KNOWLEDGE—BASED MANAGEMENT OF ALGORITHMS; VARIOUS METHODS AND MODELS ARE AVAILABLE IN PUBLIC DOMAIN
- DEVELOPMENT OF A SET OF SIMPLIFIED 'SHORT—CUT' SOLUTIONS USING STATE—OF—THE—ART SOFTWARE/TOOLS AND CURRENT METHODS AND MODELS HAS HIGHER PAYOFF THAN MODIFYING THE EXISTING ONES

V(INT)^2 SMI SYSTEM DESIGN ELEMENTS



V(INT)^2 SMI EXECUTIVE DESIGN FEATURES

- OBJECT–ORIENTED MESSAGE–PASSING ARCHITECTURE
- SCRIPT–BASED DIALOG CONTROL
- CONTEXT MAINTAINED BY MISSION/TASK AND USER PROFILES
- PRELOAD EXPECTATIONS OF KNOWLEDGE AND CALCULATIONS

SOFTWARE ARCHITECTURE FOR V(INT)^2 SMI PHASE I DEMO

SOFTWARE REQUIREMENTS

FIGURE 1

Display A	DMA Database Handler (DDH), graphics overlay.
Display B	DDH, automatic rescaling of digital data.
Display C	Text file 1.
Display D	Automated status monitoring and update.
Alert key	----------
Voice Entry	----------
Cursor Controller	----------

SOFTWARE ARCHITECTURE FOR V(INT)^2 SMI PHASE I DEMO (CONT'D)

FIG URE 2

Display A	----------
Display B	----------
Display C	Text file 2.
Display D	----------
Alert key	I/O processing.
Voice Entry	Votan processing.
Cursor Controller	----------

FIGURE 3

Display A	Graphic overlay update.
Display B	Graphic overlay update, automatic rescaling.
Display C	----------
Display D	----------
Alert key	----------
Voice Entry	Votan processing.
Cursor Controller	----------

SOFTWARE ARCHITECTURE FOR V(INT)^2 SMI PHASE I DEMO (CONT'D)

FIGURE 4

Display A	----------
Display B	Graphic overlay update, display processing.
Display C	ERB protocol, knowledge base management.
Display D	----------
Alert key	----------
Voice Entry	----------
Cursor Controller	I/O processing.

FIGURE 5

Display A	----------
Display B	----------
Display C	Display update.
Display D	----------
Alert key	----------
Voice Entry	Votan processing.
Cursor Controller	I/O processing.

ERB PROTOCOLS VS. SOURCE STIMULUS

FIGURE	INPUT (STIMULUS)	ERB PROTOCOL INVOKED
2	"SHOW TARGET ##17"	DISPLAY SPECIALIST
4	"OBJECTIVE"	KNOWLEDGE BASE MANAGER INTERCEPT OPERATION PARAMETERS DISPLAY SPECIALIST INTERCEPT OPERATION PARAMETER UPDATE SPECIALIST
5, 6	"SHOW INTERCEPT"	ROUTE FINDING / NAVIGATION SPECIALIST (COMPUTES/DISPLAYS MOST LIKELY PATH)
6, 7	"SHOW INTERCEPT ZONE"	INTERCEPT / AMBUSH RULE MANAGER
8	"SHOW AMBUSH LOCATIONS"	ROUTE FINDING / NAVIGATION SPECIALIST
9	"SHOW AMBUSH X"	NAVIGATION SPECIALIST, INTERCEPT SPECIALIST
9A	"SHOW SPECIAL AMBUSH"	KNOWLEDGE BASE MANAGER, OVERLAY FEATURE SELECTOR
10, 11	"SHOW ROUTE TO AMBUSH X"	DISPLAY SPECIALIST, KNOWLEDGE BASE MANAGER, INTERCEPT SPECIALIST, NAVIGATION SPECIALIST
12, 13 14	RPV INFO VIA ALERT	KNOWLEDGE BASE UPDATE SPECIALIST, DISPLAY SPECIALIST, NAVIGATION SPECIALIST, INTERCEPT SPECIALIST

COOPERATING SPECIALISTS FOR V(INT)^2 SMI ERB PROTOCOL DEVELOPMENT

- PATH FINDING / NAVIGATION
  - GIVEN INITIAL AND FINAL POINTS
  - FINDS ACCEPTABLE / OPTIMAL PATH(S) FOR A GIVEN SET OF CRITERIA/
  - PERFORMANCE FUNCTIONS

- INTERCEPT
  - CONSISTS OF TWO SUBSPECIALISTS
    1. TARGET PATH PROJECTION GIVEN TARGET'S INITIAL AND FINAL POINT
    2. GIVEN PROJECTED TARGET ROUTE AND SPEED, FIND A SET OF LOCATIONS ALONG TARGET ROUTE THAT SATISFY: OWN PATH FINDING; OWN ARRIVAL TIME < TARGET ARRIVAL TIME

- KNOWLEDGE MANAGEMENT
  - A META–KNOWLEDGE SOURCE IN CONTROL OF UPDATING AND INTEGRATING MULTIPLE KNOWLEDGE SOURCES

- AMBUSH OPERATION
  - A COLLECTION OF FACTS, ROEs AND CRITERIA RELATED TO AMBUSH OPERATION

- DISPLAY MANAGEMENT
  - A COLLECTION OF RULES RELATED TO OPERATOR INPUTS, CURRENT CONTEXT AND TIME THAT UPDATE VARIOUS DISPLAY WINDOWS AS NEEDED
  - RESPOND TO OPERATOR INPUTS, ELAPSED TIME, AND ONGOING TASK

TASK 1D: DEVELOPMENT OF ERB PROTOCOLS

GOAL

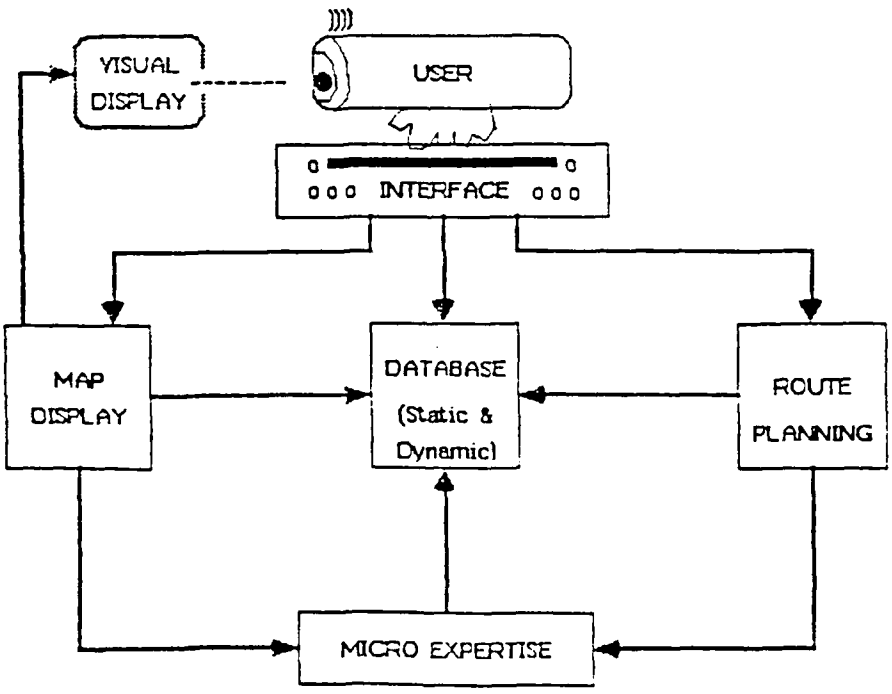
To assist TPL in planning a successful ambush by providing:

color-coded terrain maps

visibility, concealment, defilade and angular sector of fire

projected routings for friend and foe

SCHEMATIC OF V(INT)^2



DECEMBER 1 MILESTONES

- store, retrieve, manipulate and display DMA database
- compute line of sight from enemy positions
- identify and depict regions of selected trafficability

CURRENT COMPONENTS

- Map display and database
- Line of sight visibility (micro expertise)
- Route planning

CURRENT VINT2 MAP DISPLAY

- data extraction
- color-coded background displays
- contouring
- overlays
- perspective view

DATA EXTRACTION

- DMA data = 64 bits per location as sets of bit fields
- initial data had bugs, some removed by simple filtering
- can retrieve any contiguous bit field and associate values with colors

COLOR-CODED BACKGROUND DISPLAYS

- 5 bits allows 32 color shadings
- 3 mutually exclusive displays
  - terrain elevation
  - surface features
  - trafficability

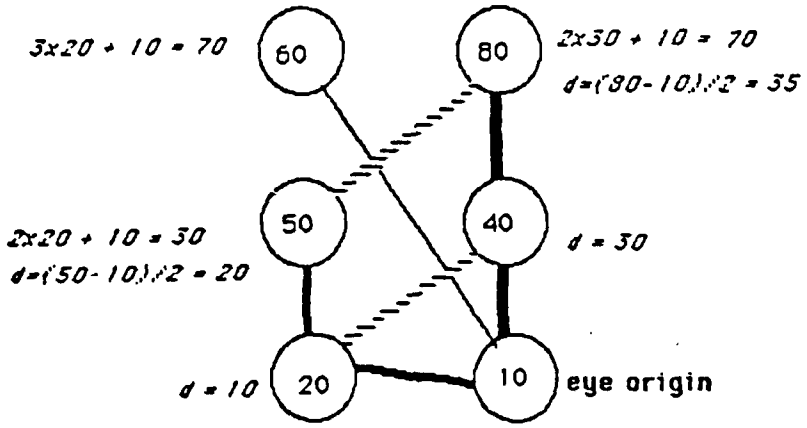
OVERLAYS

- placed over a color-coded background display
- 3 colors used for overlays
- overlay features such as:
  - roads (primary, secondary)
  - railroads
  - obstacles
  - force positions
  - intervisibility

CONTOURING

- clever algorithms tried and scrapped
- simple algorithm
  1. for each point, round value to nearest band
  2. if any of 8 neighbors of different band, shade as contour

Propagation of Visibility



Circles are grid locations with elevation numbers ins

Top equations are expected height for point to be v

d= equations compute new delta to propagate

Thick lines go to visible locations

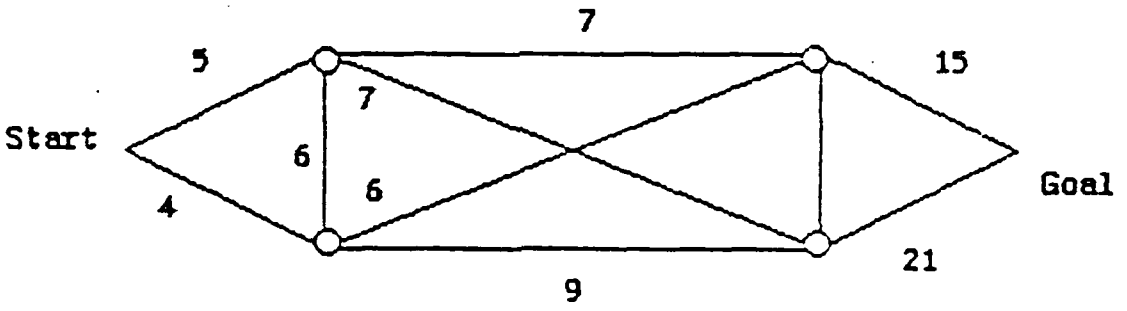
ROUTE PLANNING

- Usual paradigm is "dynamic programming"

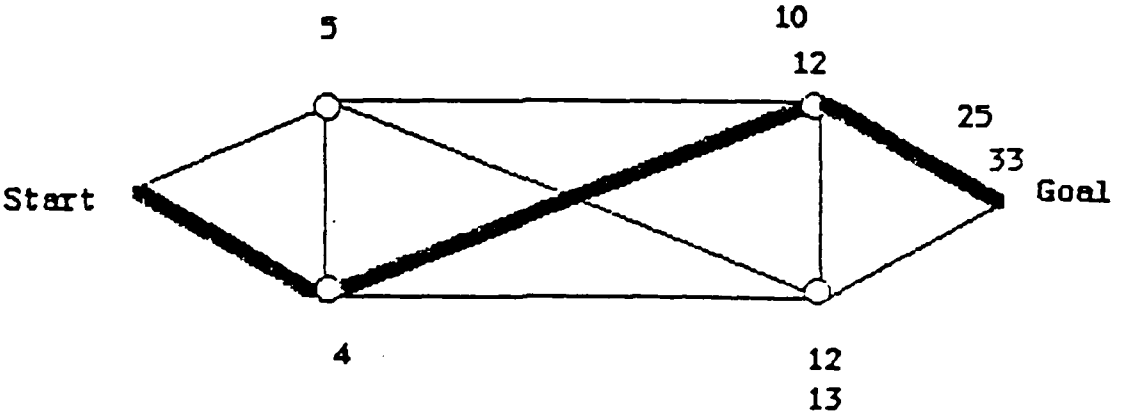
1. create a cost function for node traversal

   e.g. cost = b (height$_{new}$ − height$_{old}$) + c (distance$_{new-old}$)

2. compute costs to neighboring nodes



3. propagate minimum cost



ANALYSIS OF DYNAMIC PROGRAMMING

Advantages: easy to program
finds optimal route

Disadvantages: uniform cost for simple or hard tasks

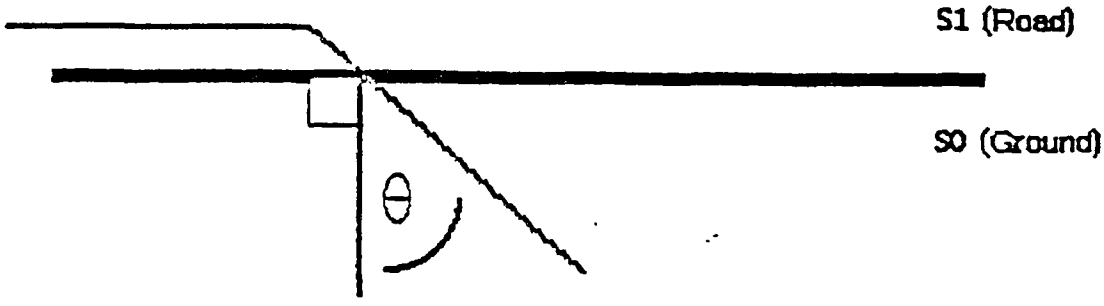
cost function is non-intuitive, inexplicable

- TPL does not see tradeoffs
- TPL does not see close second routes
- TPL trusts others for tradeoff formula

EXPERTISE

- prefer shortest lines to destination
- roads are likely routes
- when terrain changes ("obstacle"), compare going around it ("avoidance") to going through it
- laws of refraction (optics)

OPTICS LAWS IN ROUTE PLANNING



$$\text{Sin}\ \theta = \frac{S0}{S1}$$

optimal angle to depart road is computable

ROUTE PLANNING SHORTCUTS

- precompute some routes
- lump together common features into regions
- work interactively with TPL
- directed searching
- progressively refine from clusters of points down

** accept plausible routes (do not require optimal)

PROBLEMS AND SOLUTIONS

- ARTBAS tape has data anomalies
  - . let them be
  - . remove by filtering or by hand

- ARTBAS tape is unique, unsupported, unavailable for other areas
  - . switch to supported tape
  - . keep system suitable for other tape, but use ARTBAS

- Roads dominate Fulda Gap - distort optimal algorithms
  - . build system as is
  - . build system which also works if roads removed or only primary roads exist

- Symbolics hardware is barely fast enough for graphics
  - . this is prototype demo
  - . better hardware continues to evolve

FUTURE MILESTONES

- compute and display possible routes of friend and foe
- compute and display probable masking and concealment

- identify and display possible hull defilade positions
- compute and display potential intercept points
- compute and display points to command angular sector of fire

DEVELOPMENT ENVIRONMENT

- SYMBOLICS 3670
- SYMBOLICS COLOR GRAPHIC SYSTEM
- LASER GRAPHIC PRINTER
- VOTAN VOICE RECOGNITION/GENERATION SYSTEM
- PROGRAMMABLE DISPLAY PUSHBUTTON (PDP) SWITCHES
- BEETLE CURSOR CONTROLLER

SYMBOLICS 3670 SOFTWARE ENVIRONMENT

- ZETALISP LANGUAGE
- FLAVORS EXTENSION
- WINDOW SYSTEM
- REAL-TIME EDITOR
- INSPECTOR UTILITY
- FONT EDITOR
- E-MAIL CAPABILITY
- ADVANCED NETWORKING CAPABILITY
- FORTRAN 77 COMPILER

SYMBOLICS 3670 HARDWARE

- 4 MBYTES HIGH-SPEED RAM
- 474 MBYTE WINCHESTER DISK
- 45 MBYTE STREAMER TAPE
- FLOATING POINT ACCELERATOR
- 4 RS-232 SERIAL PORTS
- 10 MBIT/SEC ETHERNET INTERFACE
- HIGH RES (1100 X 900 BIT MAPPED) MONOCHROME MONITOR W/KEYBOARD AND MOUSE

SYMBOLICS COLOR GRAPHICS SYSTEM

- 2 MILLION PIXEL MEMORY
- 8 BITS/PIXEL
- 2 BILLION COLORS (256 SIMULTANEOUS)
- HARDWARE PAN AND ZOOM
- PROGRAMMABLE VIDEO SIGNAL FORMAT
- HIGH-RES (1280 X 1024) COLOR MONITOR

SYMBOLICS LASER GRAPHICS PRINTER

- MINOLTA LASER ENGINE
- 10 PAGES/MINUTE (8.5 X 11)
- 240 X 240 DOTS PER INCH
- BIT-MAPPED PRINT CAPABILITY
- SERIAL (1000 BYTES/SEC) AND PARALLEL (30,000 BYTES/SEC) INTERFACES

VOTAN VTR-6000 VOICE TERMINAL

- VOICE RECOGNITION/GENERATION CAPABILITY
- ISOLATED OR CONTINUOUS SPEAKER-DEPENDENT RECOGNITION
- LIMITED SPEAKER-INDEPENDENT RECOGNITION
- 75 DOUBLE-TRAINED WORD CAPACITY ON-BOARD
- UNLIMITED CAPACITY WITH VIRTUAL MEMORY SWAPPING
- RS-232 INTERFACE

PROGRAMMABLE DISPLAY PUSHBUTTON (PDP) SWITCHES

- 16 X 35 INDIVIDUALLY ADDRESSABLE PIXEL ARRAY
- 4 SWITCHES CONTROLLED BY A SINGLE RS-232 CARD
- CONTROLLER HANDLES REFRESH, BLINKING, ASCII CHARACTER GENERATOR

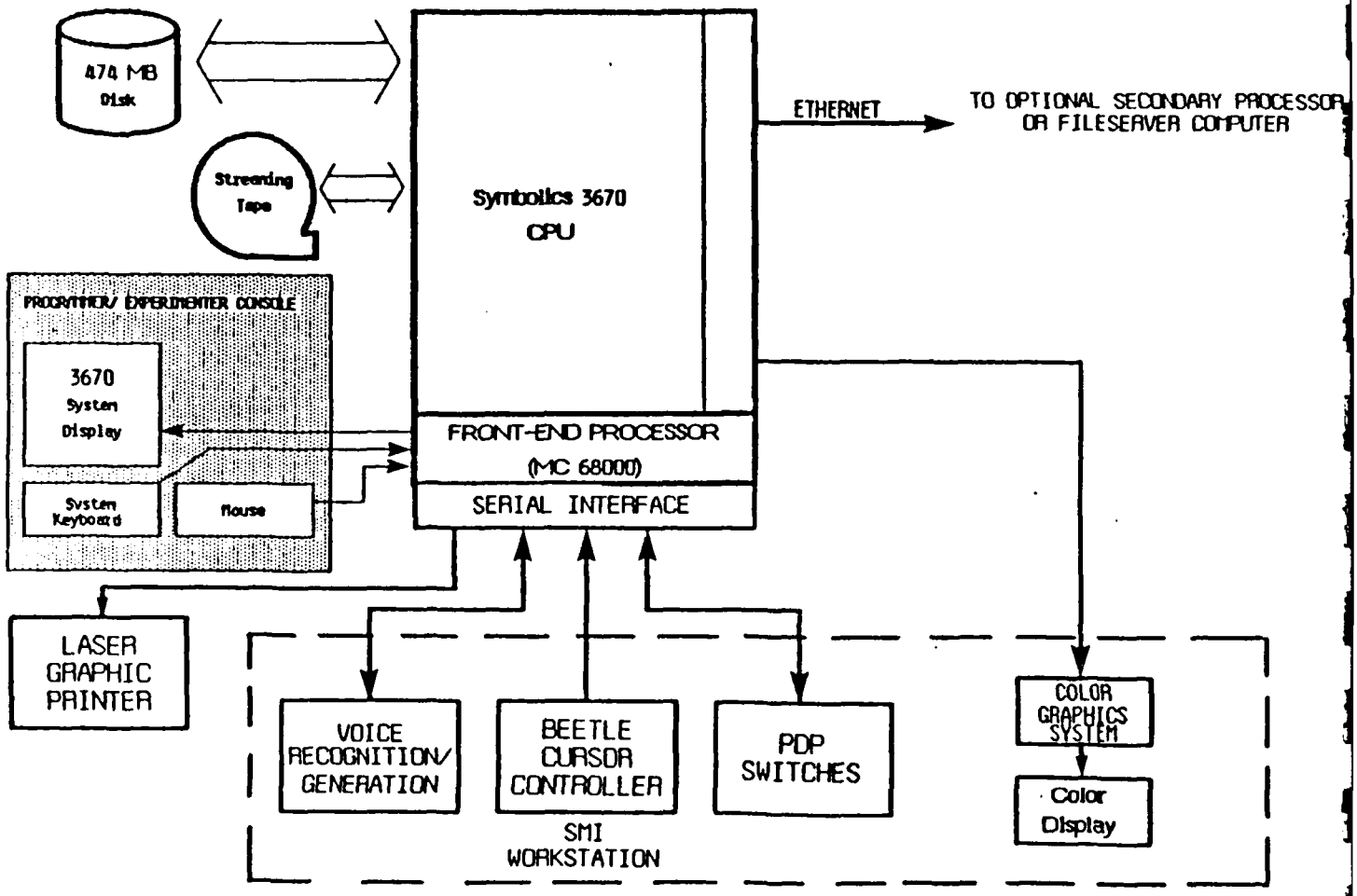
BEETLE CURSOR CONTROLLER

- INFINITE RESOLUTION (i.e. ANALOG)
- INTERNAL FORCE TRANSDUCERS AND MICROPROCESSOR
- VARIABLE SCALING FACTOR
- UP TO FOUR SOFT SWITCHES

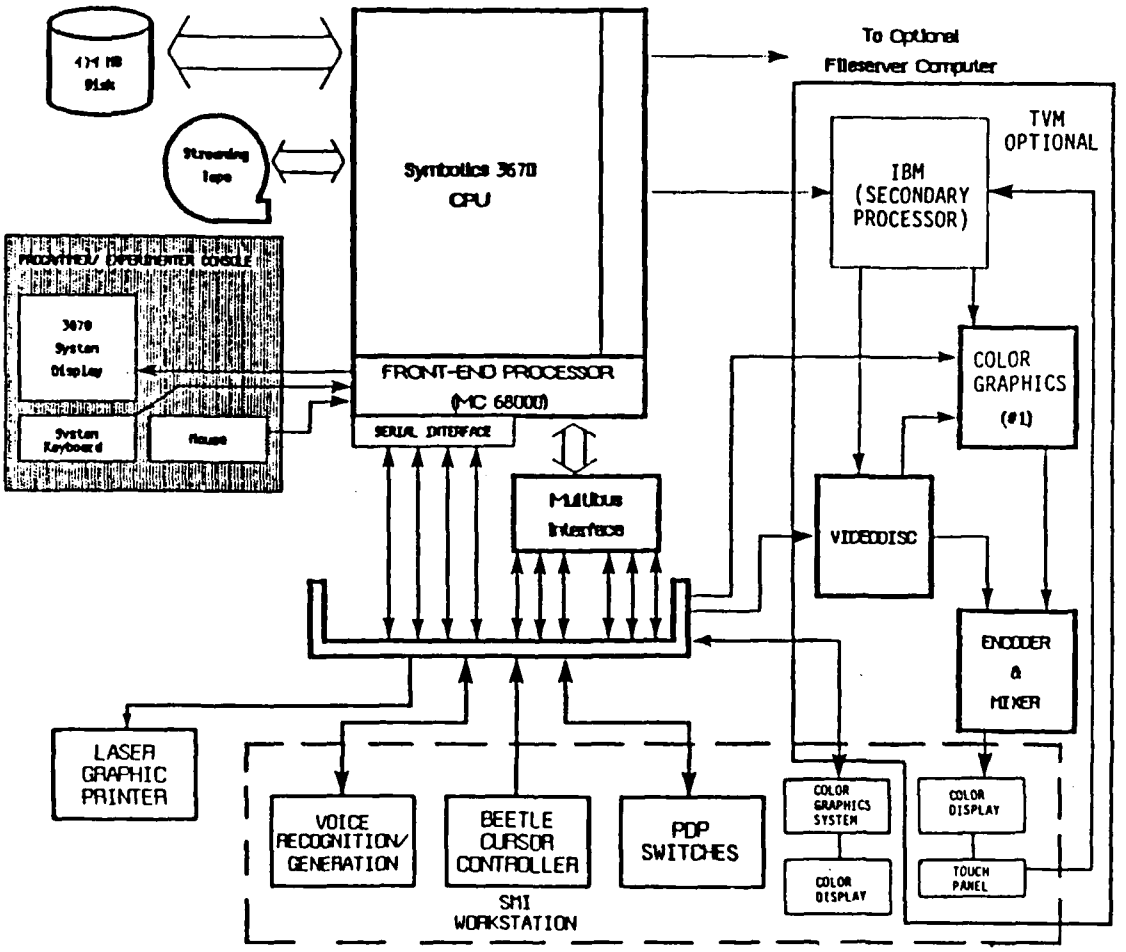
SUBSYSTEM INTEGRATION

- VOICE RECOGNITION SUBSYSTEM INTEGRATED WITH SYMBOLICS
- PDP "SOFT" SWITCHES INTEGRATED WITH SYMBOLICS
- BETTLE CURSOR CONTROLLER INTEGRATED WITH SYMBOLICS
- DEMO SCENARIO FOR DEC 4 CONSISTS OF:
  - AMBUSH OPERATION SEQUENCE
  - VOICE INPUT / GENERATION
  - PDP SWITCH INTERACTION (GRAPHIC ICON AND FLASHING TEXT)
  - CONTROL INPUTS FROM BEETLE
  - TEXTUAL DISPLAYS TO SIMULATE DMA – GRAPHICS OUTPUT

2ND IPR BENCH DEMO ARCHITECTURE

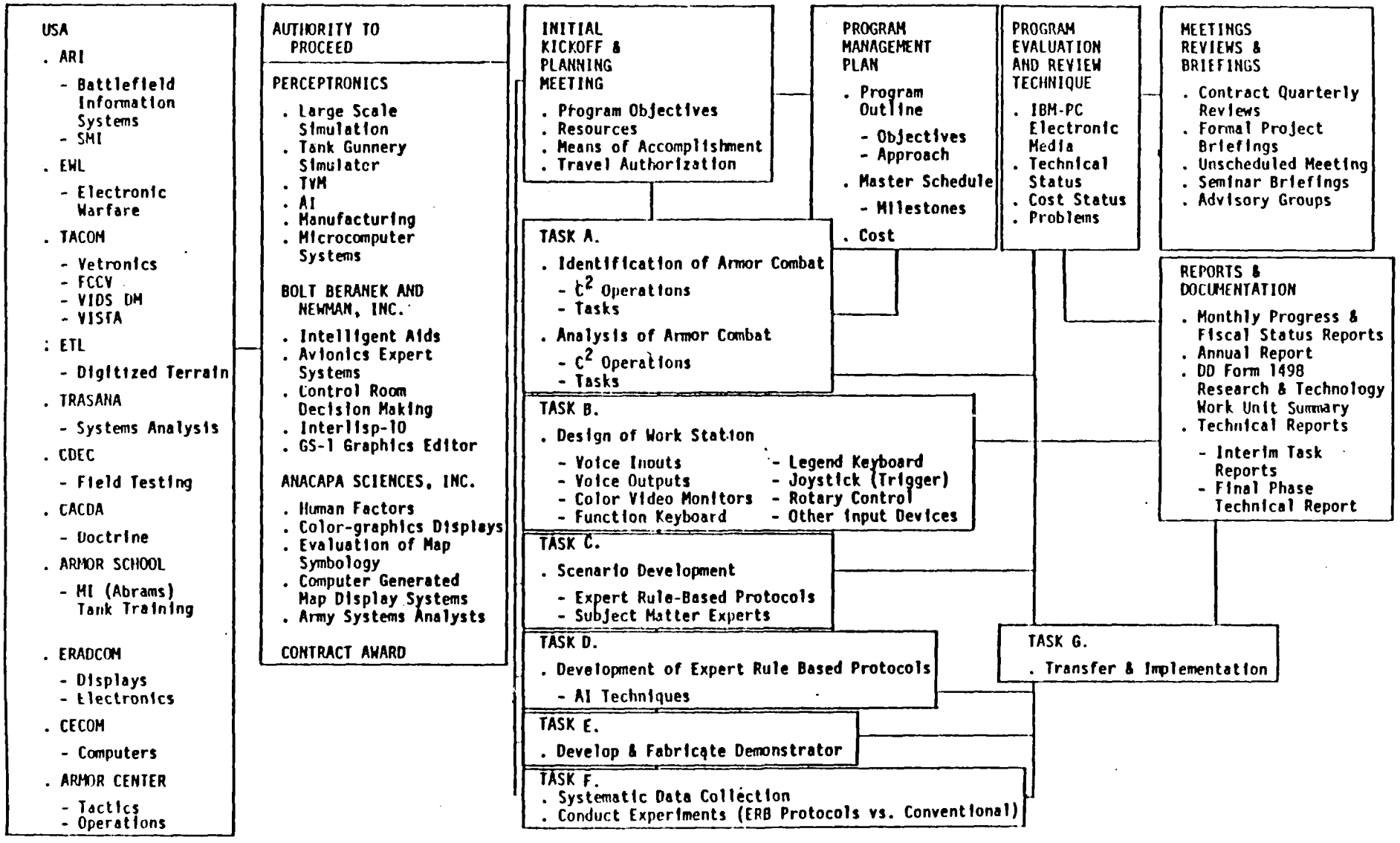


SMI SYSTEM ARCHITECTURE

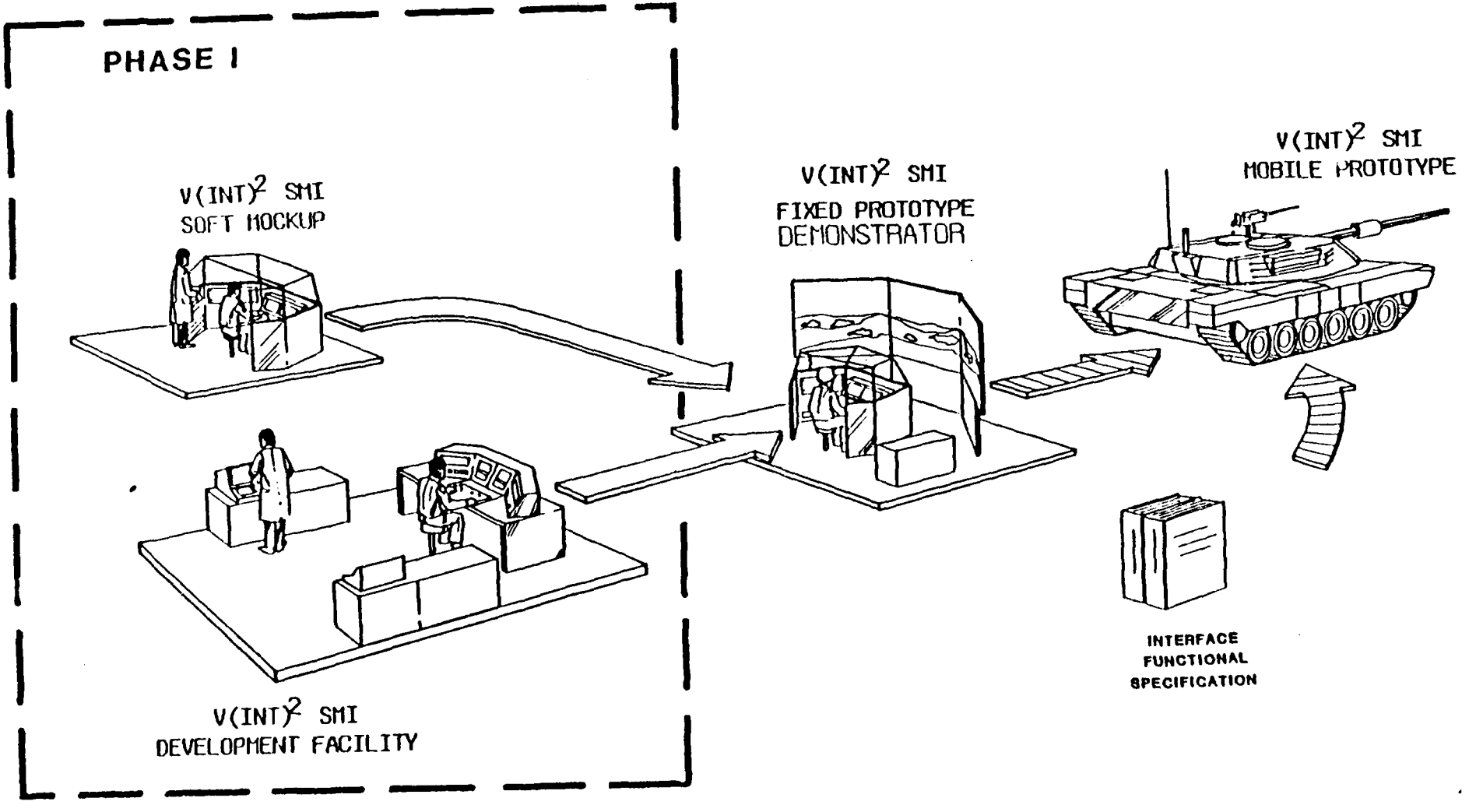


TECHNICAL SUMMARY

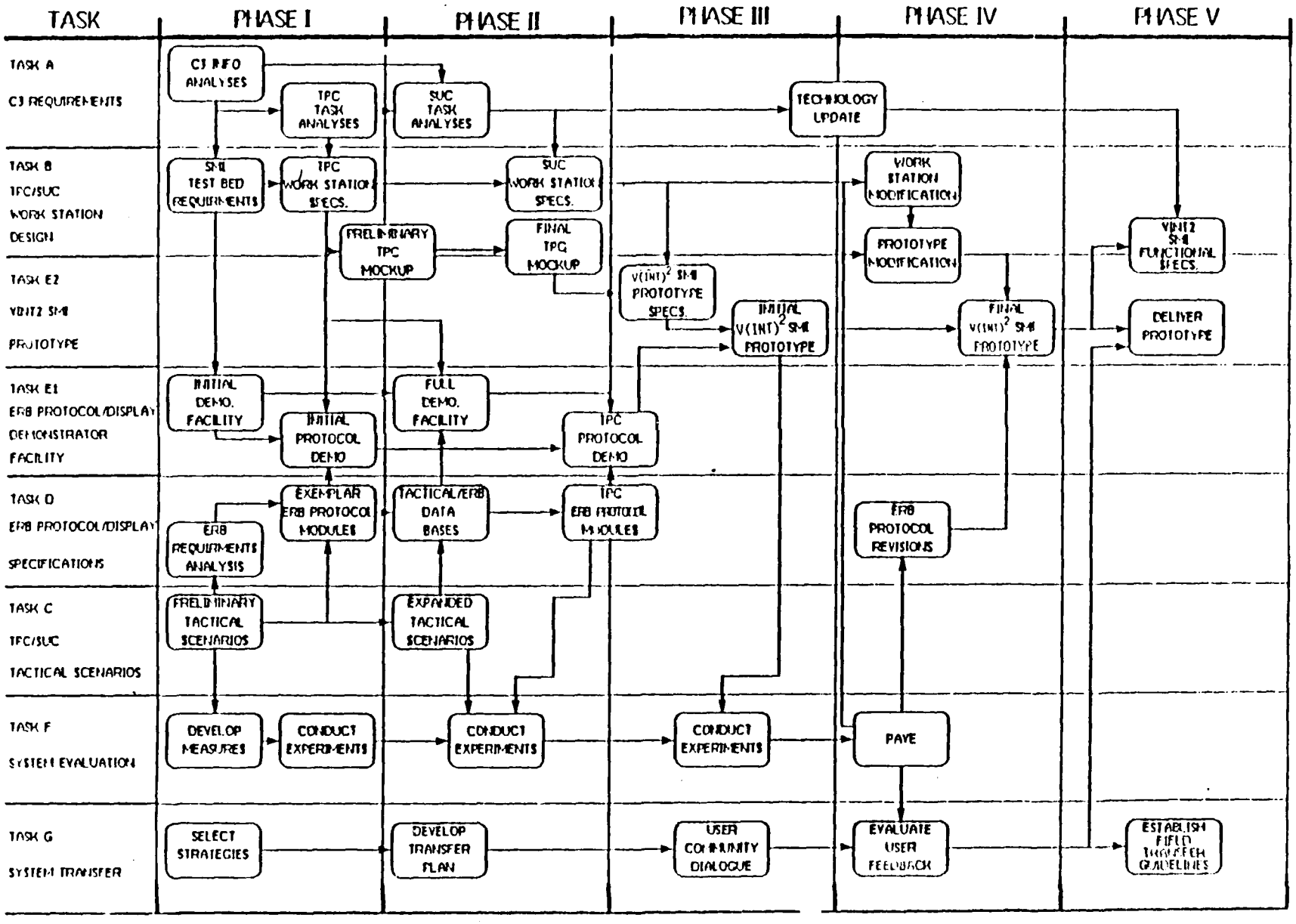
PHASE I PROGRAM PLAN



STAGES IN V(INT)^2 SMI PROTOTYPE DEVELOPMENT



V(INT)^2 SMI MAIN PROJECT MILESTONES



V(INT)^2 OPERATIONAL CONCERNS

- FUTURE LOOKING
  - OFF–LOAD COMMANDER/USER
    1. VOICE ENTRY VIA ICS
    2. STATUS BY EXCEPTION
    3. ALERTS–PROVIDE PARSED MESSAGE AND AUTOMATICALLY UPDATE UNDERLYING GRAPHICS
    4. INTEGRATE SPEED, TRAFFICABILITY, ENEMY ACTIONS TO GRAPHICS
    5. AUTOMATICALLY UPDATE CHANGES, E.G., SPEED
    6. INTEGRATE COVER, CONCEALMENT, MASKING, NOISE RADIATION FANS, ETC, TO GRAPHICS
    7. PRESENT BEST AMBUSH SITE–ONLY EXPAND OUT UPON SPECIFIC TPL REQUEST
    8. ALLOW FOR REAL–TIME IMAGE DISPLAY, E.G.S, FROM RPV's OWN/UNIT RETICLES

FUTURE WORK

- TASK IA
  - FINAL REFINEMENT OF CONTROLS AND DISPLAYS FOR DEMO SCRIPT
  - HUMAN FACTOR ALL MMI
- TASK IB
  - IDENTIFY ALL CONTROLS AND DISPLAYS FOR FUTURE INTEGRATION INTO WORK STATION "MOCK–UP"
- TASK IC
  - RECONCILE AMBUSH OPERATIONS SCENARIO TO THE "BIG PICTURE" AND PROGRAM V(INT)^2 SMI EXECUTIVE GEARED TO DEMO SCENARIO
- TASK ID
  - DEVELOP AND PROGRAM "AGREED UPON" ERB PROTOCOLS FOR DEMO SCENARIO
  - INTEGRATE ERB PROTOCOL SOFTWARE WITH V(INT)^2 SMI EXECUTIVE
- TASK IE
  - INTEGRATE DEMO SOFTWARE WITH ALL CONTROLS AND DISPLAYS
  - FINALIZE "BENCH SYSTEM" FOR PHASE I DEMO
- TASK IF
  - IDENTIFY INITIAL PERFORMANCE MEASURES
  - CONDUCT DEMO EVALUATION (PILOT EXPERIMENTS)
- TASK IG
  - MAINTAIN USER COMMUNITY INVOLVEMENT / PREPARE USER COMMUNITY FOR PHASE I DEMO "MESSAGE"?

REFERENCES

Denton, R.V., and Froeberg, P.L. Applications of Artificial Intelligence in Automated Route Planning. In **Applications of Artificial Intelligence**, proceedings of SPI, **485**, 126-132, 1984.

Ericsson, K.A., and Simon, H.A. **Protocol Analysis: Verbal Reports as Data.** Cambridge, Massachusetts: The MIT Press, 1984.

Madni, A.M. **Artificial Intelligence Approaches in Intelligent Helicopter Automation for Nap-of-the-Earth Missions,** Report PFTR-1136-84-3). Woodland Hills, California: Perceptronics, Inc., March 1984.

Madni, A.M., Chu, Y., Purcell, D., and Brenner, M.A. **Design for Maintainability with Modified Petri Nets (MPNs),** Report PATR-1125-84-11. Woodland Hills, California: Perceptronics, Inc., November 1984.

Madni, A.M., Fielding, M.R., and Sidorsky, R.C. **ARI V(INT)^2 Demonstrator: Initial Scenario and Functional Specification,** Army Research Institute Research Note 85-27, January 1985.

Peterson, J.L. Petri Nets. **Computing Surveys,** 9(3), 223-252, 1977.

Zisman, M.D. Use of Production Systems for Modeling Asynchronous Concurrent Processes. In D.A. Waterman and F. Hayes-Roth (Eds.) **Pattern-Directed Inference Systems,** Academic Press, 53-68, 1978.